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Key Points:
- Paleo-reconstructed temperature-salinity diagrams indicate decadal shifts in source water mixing in the southern Makassar Strait
- The East Asian winter monsoon influences surface water circulation into the Makassar Strait interannually
- Shifts in Indo-Pacific climate state likely influence circulation throughout the South China Sea and Indonesian Seas

Supporting Information:
- Supporting Information S1

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Climatic Influences on Southern Makassar Strait Salinity Over the Past Century

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Abstract The Indonesian Throughflow (ITF) is a globally important ocean current that fuels heat and buoyancy fluxes throughout the Indo-Pacific and is known to covary in strength with the El Niño Southern Oscillation at interannual time scales. A climate system with a less well-quantified impact on the ITF is the East Asian Winter Monsoon (EAWM), which drives less saline surface waters from the South China Sea (SCS) into the Makassar Strait, obstructing surface ITF flow. We present a subannually resolved record of sea surface salinity (SSS) from 1927 to 2011 based on coral $\delta^{18}O$ from the Makassar Strait that reveals variability in the relative contributions of different source waters to the surface waters of the Makassar Strait during the boreal winter monsoon. We find that the EAWM (January–March) strongly influences interannual SSS variability during boreal winter over the twentieth century ($r = 0.54$, $p << 0.0001$), impacting surface water circulation in the SCS and Indonesian Seas.

1. Introduction

The Indonesian Throughflow (ITF), driven by sea level pressure differences between the Pacific and Indian Oceans (Wyrtki, 1961; Wyrtki, 1987), transfers ~15 sverdrups (1 Sv = 10^6 m^3/s) of seawater and up to 10^{15} watts of heat from the western equatorial Pacific into the Indian Ocean (Godfrey, 1996; Gordon et al., 2010; Sprintall et al., 2014; Vranes et al., 2002). The ITF thus impacts regional air-sea heat exchange and Indo-Pacific ocean and climate systems. Interannual ITF variability is connected to the El Niño Southern Oscillation (ENSO). Regional winds over the Indonesian archipelago reflect the influence of both the East Asian summer monsoon, defined using meridional or zonal land-sea temperature differences (e.g., Shi & Zhu, 1996; Webster & Yang, 1992), and the East Asian winter monsoon (EAWM), defined as the pressure difference between the Siberian High and Aleutian Low (Chen et al., 2004), impacting precipitation and ocean circulation patterns (Gordon et al., 2012; Meyers, 1996; Murtugudde et al., 1998; Vranes et al., 2002; Wyrtki, 1961).

Seasonally reversing monsoonal winds alter the strength of the ITF (Gordon et al., 2003; Hautala et al., 2001). From July through September, boreal summer monsoon winds augment the sea level gradient between the two oceans, intensifying the ITF (Wyrtki, 1987). At this time, the monsoonal winds also drive upwelled Banda Sea water into the southern Makassar Strait (Gordon et al., 2003; Figure 1a). The winds reverse during the boreal winter monsoon (January–March), reducing sea level pressure anomalies and weakening the ITF (Wyrtki, 1987). The winter monsoon winds further restrict surface ITF flow by driving South China Sea Throughflow (SCSTF) waters from the Java Sea into the southern Makassar Strait, and from the Luzon Strait (Gordon et al., 2014) into the northern Makassar Strait (Gordon et al., 2012; Xu & Malanotte-Rizzoli, 2013; Figure 1a). The buoyant SCSTF waters block southward surface ITF flow and the associated heat flux, driving its primary flow toward cooler thermocline depths (Gordon et al., 2003, 2012; Xu & Malanotte-Rizzoli, 2013).

While most previous work has examined ITF variability over the past 1,000–140,000 years using sediment cores (Holbourn et al., 2011; Linsley et al., 2010; Oppo et al., 2009), the records do not have enough temporal resolution to distinguish seasonal monsoon-driven variability. Coral archives, however, provide high-resolution (subannual), century-long climate reconstructions due to high linear extension rates and annual banding patterns (Corrège, 2006). Previous studies have used high-resolution coral records throughout the

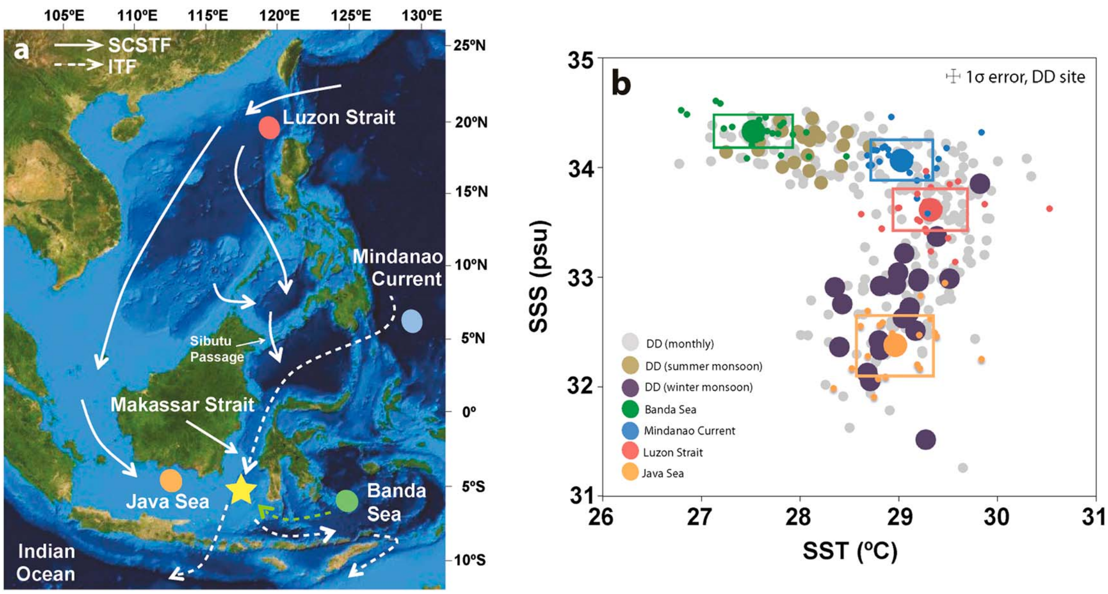

Figure 1. Surface water transport in the southern Makassar Strait. (a) Map of the South China and Indonesian Seas with circles indicating source water locations and arrows indicating pathways of the Indonesian Throughflow (ITF, dotted white), South China Sea Throughflow (SCSTF, solid white), and wind-driven Banda Sea water (green). The yellow star represents the coral site. (b) HadISST-SODA SSS temperature-salinity diagrams for Doangdoangan Besar (DD) at monthly (gray) and interannual resolution (brown, boreal summer monsoon and purple, boreal winter monsoon) for 1985–2005. Dot size indicates 1σ error. Instrumental seasonal averages (July–September (JAS): Mindanao Current, Banda Sea; January–March (JFM): Java Sea, and May–July (MJJ): Luzon Strait) for source water locations are plotted with a box of one standard deviation.

pathway of the ITF to reconstruct interannual variability in ENSO and the South Pacific Convergence Zone (SPCZ) (Charles et al., 2003; Fairbanks et al., 1997; Fallon & Guilderson, 2008; Linsley et al., 2017; Moore, 1995). These studies have collectively shown that the temperature, salinity, and radiocarbon characteristics of the ITF have varied over the past few hundred years on interannual to interdecadal time scales as western Pacific Ocean circulation dynamics changed in response to ENSO and SPCZ zonal events. However, while the published sites are along the ITF pathway, they are not optimally located to investigate the monsoon-driven surface water circulation in the SCS and Indonesian Seas that impacts the ITF at seasonal and interannual time scales. For example, Fallon and Guilderson (2008) note that their coral site (Langkai) may be located too far east in the Makassar Strait to record the wind-driven winter monsoon buoyancy plug, but acknowledge the possibility of a combined monsoon and ENSO influence at interannual time scales. Similarly, Linsley et al. (2017) show that Kapoposang experiences truncated winter monsoon freshening during SPCZ zonal event years, when the inflow of higher salinity water from the northern Makassar Strait prevents the lower salinity Java Sea waters from reaching the eastern Makassar Strait. Seasonal and interannual monsoon influences should therefore be better resolved at sites in the center of the southern Makassar Strait, farther west of the previously published records.

Here we build upon previous coral-based climate records by reconstructing sea surface salinity (SSS) at Doangdoangan Besar (DD) in the center of the southern Makassar Strait to examine surface water mixing and circulation over the twentieth century. The DD site is optimal for examining surface mixing, as it is located in the main ITF pathway and is far enough west to consistently receive the seasonal, monsoon-driven SCSTF contribution via the Java Sea. The coral climate proxy $\delta^{18}O$ ($^{18}O/^{16}O$) contains a combined sea surface temperature (SST) and SSS signal (Dunbar & Wellington, 1981; Epstein et al., 1953). Once the temperature signal is removed, coral $\delta^{18}O$ from a more central site should record SSS variability at temporal resolutions high enough to distinguish the influence of the EAWM on surface water circulation in the Makassar Strait, through which 80% of the total ~15 Sv of ITF water flows (Gordon et al., 2010).

2. Data and Methods

In April 2013, a *Porites* spp. coral was drilled from Doangdoangan Besar (DD: 5.382°S, 117.914°E) in the southern Makassar Strait (Figure 1). The island is centrally located within the strait and is bathed alternately in southward flowing ITF waters during the summer monsoon (July–September) and northward flowing SCSTF waters during the winter monsoon (January–March) (Gordon et al., 2003).

Cores were cut into 0.5 cm thick slabs, and x-radiographs were taken to visualize density banding patterns (Figure S1 in the supporting information). Sampling pathways were identified based on the x-rays and on corallite orientation (DeLong et al., 2007, 2013). Subsamples were drilled at 0.5 mm (<biweekly) resolution using a manual drill press, resulting in a high-resolution record spanning 27 years used to calibrate the coral proxy data. To examine interannual variability, the DD coral was also sampled at lower (3 mm, ~6 samples/yr) resolution for a record spanning 85 years. Each drilled sample consisted of ~40–200 μg for $\delta^{18}O$ analysis.

$\delta^{18}O$ measurements were conducted at the Earth Observatory of Singapore (EOS) and the Australian National University (ANU). At EOS, samples were acidified with 105% H_3PO_4 at 70°C using an automated Kiel IV carbonate device coupled with a ThermoFisher MAT-253 Isotope Ratio Mass Spectrometer (IRMS). At ANU, samples were acidified with 105% H_3PO_4 at 90°C using an automated individual-carbonate reaction Kiel device coupled with a Finnigan MAT-251 IRMS. All isotopic measurements at ANU and EOS were calibrated relative to Vienna Peedee Belemnite using National Bureau of Standards (NBS) 19 ($\delta^{18}O = -2.20‰$) and NBS 18 ($\delta^{18}O = -23.2‰$) (Stichler, 1995). The reproducibility of NBS 19 is 0.04‰ (1σ, $n = 165$) and 0.03‰ (1σ, $n = 10$) for ANU and EOS, respectively. Estremoz and Borba standards were also used to cross calibrate the ANU and EOS instruments, showing no measureable offset between labs or against published values. Additionally at EOS, Estremoz, Carrarra and TSF were routinely measured, yielding average values and errors of $-5.956 \pm 0.08‰$, $-1.938 \pm 0.05‰$, and $-2.281 \pm 0.07‰$, respectively (total of all standards, $n = 688$).

Simple Ocean Data Assimilation SSS (SODA SSS reanalysis, v. 2.2.4; Carton & Giese, 2008) from a 0.5° × 0.5° grid (centered at 5.25°S, 117.75°E) was used to evaluate salinity. Other available SSS products do not extend into the Indonesian Seas (Delcroix et al., 2011) or do not cover the temporal range of the coral record (e.g., Aquarius; Lagerloef et al., 2008). Because the Aquarius and SODA records do not overlap, we were unable to evaluate biases in the two products. However, a comparison of SODA upper 10 m salinity and 10 m salinity from conductivity-temperature-depth casts in the same grid cell in the southern Makassar Strait has shown that overall, SODA SSS is accurately representing salinity variability in the Makassar Strait (Linsley et al., 2017, and references therein).

Gridded SST from Hadley Center for Sea Ice and Sea Surface Temperature (HadISST, version 1.1, Rayner et al., 2003) from 1° × 1° grids (centered at 5.5°S, 117.5°E) was used to examine SST. Because we directly removed the gridded SST signal to calculate $\delta^{18}O_{sw}$, we were limited to using temperature products that extend the length of the coral record.

Both SST and $\delta^{18}O_{sw}$ (related to changes in the hydrologic cycle and ocean circulation) influence the $\delta^{18}O_{coral}$ proxy signal (Epstein et al., 1953; Grossman & Ku, 1986; McConnaughey, 1989; Weber & Woodhead, 1972). Seasonal SST variability at DD is relatively low (on average 2.1°C), while average SSS variability is 2.2 practical salinity units (psu). Thus, we assume that SSS drives the $\delta^{18}O_{coral}$ signal and is better used to develop the age model. To assess this methodological approach, we calculated the contribution of SST to the $\delta^{18}O_{coral}$ signal, using a $\delta^{18}O$-SST slope of $-0.18‰$/°C (Gagan et al., 1998) and a range of published $\delta^{18}O$-SSS slopes (Moore, 1995; Fairbanks et al., 1997; Gorman et al., 2012; Morimoto et al., 2002; Conroy et al., 2017; Table S1 and supporting information text). We estimate that SST has a 29–39% influence on the $\delta^{18}O_{coral}$, supporting our approach of using the relationship between $\delta^{18}O_{coral}$ and SSS to derive the age model.

Using SODA SSS, subannual age models were established using AnalySeries version 2.0 software (Paillard et al., 1996). Minima, maxima, and inflection points of the $\delta^{18}O_{coral}$ seasonal cycle were aligned to the SODA SSS seasonal cycle. The $\delta^{18}O_{coral}$ time series was then interpolated to monthly increments to match the SODA SSS product. Calibrations of interpolated $\delta^{18}O$ to SSS were performed using type-II least squares linear regressions.

3. Observed SST and SSS Variability in the Southern Makassar Strait

Temperature-Salinity (T-S) diagrams at the DD coral site of HadISST (centered at 5.5°S, 117.5°E) and SODA SSS (centered at 5.25°S, 117.75°E) further support that the southern Makassar Strait is a region of surface seawater mixing (Figure 1). At monthly resolution from 1985 to 2005, the T-S diagram shows a curved pattern,

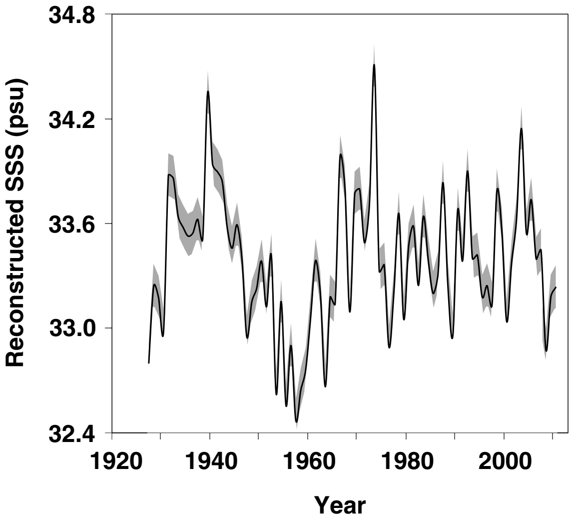

Figure 2. Record of reconstructed SSS variability from Doangdoangan Besar (DD) using its $\delta^{18}O_{sw}$-SSS calibration (equation (1)). The boreal winter monsoon record is shown (black), revealing a rapid salinity shift from 1945 to 1965. The gray shaded area indicates RMSR = 0.1 psu.

indicating multiple source waters mixing seasonally. Three-month averages of HadISST and SODA SSS from the Mindanao Current and the Banda Sea during the summer monsoon (July–September) indicate that both locations could contribute to the Makassar Strait surface waters (Figure 1). Similarly, 3-month averages from the Java Sea (January–March) and Luzon Strait (May–July) indicate that both sites could play a role during the winter monsoon (Figure 1). This assumes an offset in Luzon Strait timing that may be due to an average residence time of the Luzon Strait water in the SCS during the summer monsoon prior to winds shifting to push the water into the Makassar Strait during the winter monsoon.

4. Results

Monthly-resolution $\delta^{18}O_{coral}$ from a *Porites* coral at Doangdoangan Besar (DD) in the center of the southern Makassar Strait shows an average seasonal cycle of 0.9‰ (Figure S2). Converting the $\delta^{18}O_{coral}$ record to $\delta^{18}O_{sw}$ by directly removing the HadISST signal (see supporting information text and equations (S1) and (S2)), we find an average $\delta^{18}O_{sw}$ seasonal cycle of 0.8‰ that shows similar seasonality to the $\delta^{18}O_{coral}$ record (Figure S2). The similarity between the $\delta^{18}O_{sw}$ and $\delta^{18}O_{coral}$ proxies confirms that SSS drives the majority of the oxygen isotope variability. A least squares linear regression of monthly $\delta^{18}O_{sw}$ to SODA SSS shows a significant correlation (see also Figure S3):

$$\delta^{18}O_{sw}\,(1986\text{–}2008)\,(‰) = 0.473\ (\pm 0.024)\times \text{SSS}\,(\text{psu})\text{–}15.962\,(\pm 0.806) \tag{1}$$

(r = 0.78, $p << 0.0001$, n = 257, root-mean-square residual (RMSR) = 0.03 psu).

While the freshwater end member (y intercept) of the DD $\delta^{18}O_{sw}$-SSS relationship is more depleted than what is usually observed in the tropics (Griffiths et al., 2009; Moerman et al., 2013), it is in line with observations from orographic regions in Papua New Guinea and with a regional North Pacific $\delta^{18}O_{sw}$-SSS relationship (Permana et al., 2016; LeGrande & Schmidt, 2006; see supporting information text).

We applied the DD $\delta^{18}O_{sw}$-SSS calibration (equation (1)) down core to reconstruct SSS in the Makassar Strait for the past 85 years (Figure S4). We then focused on the SSS reconstruction for the winter monsoon due to the greater degree of SSS variability during this time from mixing between the Luzon Strait and Java Sea waters (Figure 1b).

Our interannual SSS record during the winter monsoon (RMSR = 0.1 psu) reveals a rapid salinity shift from 1945 to 1965 (Figure 2). SSS freshens from 1945 to 1957, with minimum salinities reaching ~32.5 psu, before rising until ~1965. Noting this trend, we considered whether the rapid salinity shift could be due to changes in source water mixing in the southern Makassar Strait or changes to SSS at the source water locations. To better constrain past changes in SSS variability, we examined T-S mixing diagrams using the reconstructed SSS record for the winter monsoon. While local precipitation may impact SSS at weekly to monthly time scales, it is unlikely to have large impacts on annual to decadal scales at the DD site where distinct water bodies are mixing. Linsley et al. (2017) support this assumption, concluding that precipitation does not significantly impact SSS in the eastern Makassar Strait.

T-S diagrams using reconstructed SSS and instrumental HadISST at the DD site reveal both rapid changes in relative mixing in the southern Makassar Strait and gradual freshening at the source water sites. During the winter monsoon, the decadally averaged coral record (centered on the start of each decade, e.g., 1930; RMSR = 0.1 psu) and decadally averaged HadISST and SODA SSS averages for the Luzon Strait and Java Sea continue to indicate mixing between the two SCSTF source waters at the DD site (Figure 3). From 1930 to 1940, the similarity of the winter monsoon coral record (decadal averages and seasonal time series) to the Luzon Strait HadISST and SODA SSS records suggests that higher salinity Luzon Strait waters were dominantly influencing mixing at this time (Figures 3a and 3c). Notably, in 1950 the coral record shifts to similar temperature and salinity characteristics as recorded in the Java Sea record, indicating a change to

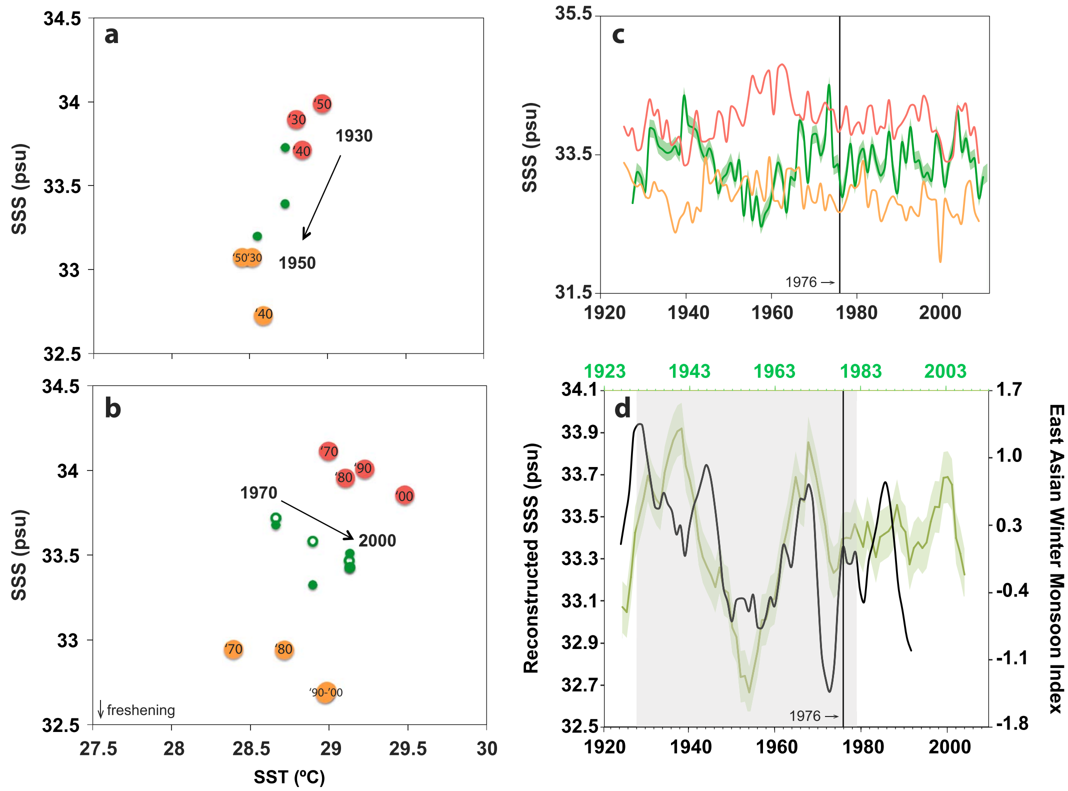

Figure 3. Records of surface water mixing and EAWM influence on reconstructed SSS. (a) T-S diagram using winter monsoon reconstructed SSS and HadISST at decadal time scales from 1930 to 1950 (green, RMSR = 0.1 psu). The Luzon Strait (red, MJJ) and Java Sea (yellow, JFM) source waters are similarly plotted at decadal time scales using SODA SSS and HadISST. From 1930 to 1950, reconstructed SSS shifts from Luzon Strait to Java Sea water. (b) T-S diagram using winter monsoon reconstructed SSS and HadISST at decadal time scales from 1970 to 2000 (green: open, SODA SSS; closed, reconstructed SSS, RMSR = 0.1 psu). The Luzon Strait (red, MJJ) and Java Sea (yellow, JFM) source waters are similarly plotted at decadal time scales using SODA SSS and HadISST. During this period, freshening influences DD and source waters similarly. (c) Records of reconstructed SSS (green, shading indicates RMSR = 0.1 psu) and SODA SSS from the Luzon Strait (red) and Java Sea (yellow) for the winter monsoon reveal the rapid salinity shift from 1945 to 1965. The vertical black line indicates the 1976 Indo-Pacific climate shift. (d) Reconstructed SSS during the winter monsoon (green, 3 year lag, green shading indicates RMSR = 0.1 psu) plotted with the EAWM index. Records were smoothed with a 5 year running mean. The black time axis corresponds to the EAWM index. EAWM wind strength is strongly correlated to the coral record from 1928 to 1979 (shaded; $r = 0.54$ and $p << 0.0001$). The vertical black line indicates the 1976 Indo-Pacific climate shift.

the relative contribution of lower salinity Java Sea waters. The subsequent SSS increase following 1960 moved Makassar Strait salinities in between those of both source waters, suggesting a more even contribution from the two sites. Following the rapid 1945–1965 salinity shift, the region exhibits gradual warming and freshening at decadal time scales that is also apparent in both the Luzon Strait and the Java Sea records (Figure 3b). Our record implies that in addition to higher-frequency mixing variability during this period (Figure 3c), there was likely a larger shift in the regional influence that impacted both the SCS and Indonesian Seas.

Statistical analysis indicates that the low-frequency shifts in SSS variability correlate to changes in the EAWM. While both this work and previous studies demonstrate that surface variability is significantly coherent with the SOI (http://www.cpc.ncep.noaa.gov/data/indices) across 2–7 year frequencies (90% confidence interval; Figure S5 and supporting information text on ENSO and EAWM climate indices), the EAWM also strongly influences interannual variability in the coral record. The reconstructed SSS record significantly correlates to the EAWM at frequencies of $<$2 years/cycle and 4–5 years/cycle, with a 3 year lag of SSS to the EAWM (90% confidence interval; Figure S5). While we cannot offer a quantitative explanation for the mechanism resulting in the 3 year lag, we hypothesize that the lag is related to the residence time of SCS waters in both the northern and southern gyres prior to moving into the Makassar Strait (Xu & Malanotte-Rizzoli, 2013).

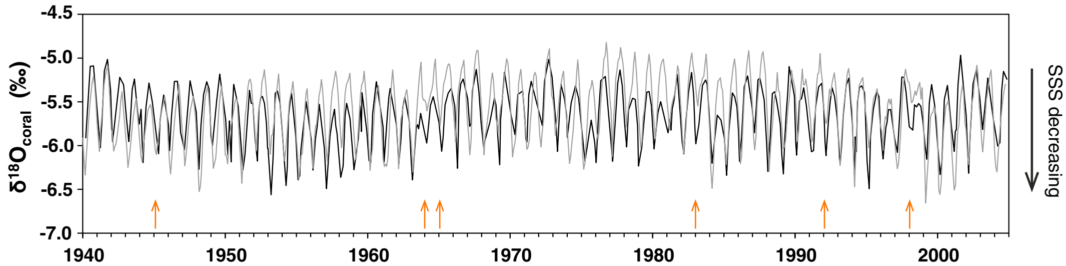

Figure 4. Time series of $\delta^{18}O_{coral}$ from the southern Makassar Strait. Bimonthly resolution $\delta^{18}O_{coral}$ from DD (black line; this study) compared to a composite $\delta^{18}O_{coral}$ record from Kapoposang and Langkai (gray line; Linsley et al., 2017). Orange arrows show SPCZ zonal events as identified by Linsley et al. (2017). The DD record does not show a consistent response to the SPCZ zonal events, as the minima (low SSS) during many events are not dampened.

However, further examination of this mechanism is beyond the scope of this study and is well suited for future work. To further investigate decadal scale variability, we employ a 5 year running mean. From 1928 to 1979, the 5 year running mean EAWM Index (D'Arrigo et al., 2005) strongly correlates with the reconstructed SSS record (r = 0.54, p <<0.0001, and n = 52; Figure 3d), including the period of rapidly shifting SSS in the southern Makassar Strait.

5. Influence of the EAWM on Surface Water Mixing in the Southern Makassar Strait

Variability in EAWM strength may strongly influence surface water mixing in the southern Makassar Strait, particularly from 1928 to 1979. In the SCS, seasonally reversing wind stress is the dominant driver of surface circulation (e.g., Fang et al., 2009; Shaw & Chao, 1994; Wyrtki, 1961; Xu & Malanotte-Rizzoli, 2013). During the winter monsoon, winds drive ~2.9 Sv of water from the Luzon Strait and ~3.6 Sv of water from the Java Sea into the Makassar Strait (Xu & Malanotte-Rizzoli, 2013). EAWM wind strength has varied at interannual to decadal time scales over the twentieth century, with winds weakening in the 1940s, subsequently strengthening until the 1970s and weakening again in the late 1970s (D'Arrigo et al., 2005; Song et al., 2012; Xu et al., 2006; Figure 3d). The weakening monsoon in the 1930s and 1940s corresponds to the rapid decrease in SSS in the coral record, while the subsequent strengthening monsoon in the 1950s and 1960s corresponds to the rapid salinity increase (Figure 3d). Corresponding changes to SSS and the EAWM coincide with observed changes to the relative mixing of Luzon Strait (high SSS) and Java Sea (low SSS) waters (Figures 3a–3c). While previous studies have identified the role of the monsoon-driven low salinity Java Sea buoyancy plug in impacting Makassar Strait SSS (e.g., Fang et al., 2010; Gordon et al., 2003), our results identify a secondary role of the EAWM. As the monsoon winds strengthen, the Luzon Strait contribution surpasses that of the Java Sea, resulting in higher SSS in the southern Makassar Strait. Our results suggest that EAWM wind strength in both the Java Sea and Luzon Strait regions collectively impacts SSS variability.

Xu and Malanotte-Rizzoli (2013) examined decadal SCS circulation differences between the 1960s (stronger monsoon) and the 1990s (weaker monsoon) using a finite volume coastal ocean model. During winter, the authors found a stronger cyclonic tendency in the southern SCS (3×10^{-7} N/m^3) and a weaker cyclonic tendency in the northern SCS (1.5×10^{-7} N/m^3) in the 1990s compared with the 1960s. Weaker circulation in the northern SCS when the EAWM is weak could reduce the relative contribution from the Luzon Strait, while stronger southern circulation could simultaneously increase the Java Sea contribution to the Makassar Strait. Both changes in advection would result in lower SSS when the EAWM is weak. Focusing on the period of maximal correlation (1928–1979), a similar mechanism can be invoked. As the EAWM weakens, advection of low SSS Java Sea water increases while high SSS Luzon Strait advection decreases, and vice versa.

In the late 1970s, EAWM wind strength decreased (Song et al., 2012; Xu et al., 2006), occurring simultaneously with the increase in the frequency of ENSO warm phases that defined the 1976 Indo-Pacific climate shift (Guilderson & Schrag, 1998; Trenberth & Hoar, 1996). Following the Indo-Pacific climate shift, the EAWM describes less of the variability in Makassar Strait SSS (Figure 3d), and water mass mixing ceases to be the dominant factor influencing SSS variability (Figures 3a and 3b). From 1970 to 2000, relative mixing is less variable than the overall declining SSS in both source water locations and in the Makassar Strait.

While EAWM relative mixing is less variable after the climate shift (Figure 3b), our results indicate that closer to the Java Sea, the EAWM continues to seasonally impact SSS, including during South Pacific Convergence Zone (SPCZ) zonal events (Figure 4). In contrast, Linsley et al. (2017) observe dampened seasonal freshening during SPCZ zonal event years. Comparing our results to theirs (Figure 4), in four of the six SPCZ zonal events (as identified by Linsley et al. 2017), Linsley et al. see truncated seasonal freshening from the Java Sea while our study does not. The Linsley et al. record is compiled from several corals located along the easternmost edge of the Makassar Strait. It is likely that while the monsoon-driven Java Sea buoyancy plug does not reach the easternmost sites, it continues to impact the DD site farther west. At DD, this continued monsoon influence likely decreases the contribution of southward flowing waters that are impacted by SPCZ zonal events. Our results suggest that although the Indo-Pacific climate shift likely reduced the EAWM influence on decadal variability, seasonally the EAWM continued to impact surface water circulation.

Climate reconstructions over the past 2,000 years have shown that monsoon and Intertropical Convergence Zone (ITCZ) dynamics strongly impact hydrologic conditions in the tropics (Newton et al., 2006; Oppo et al., 2009). Our results, however, highlight that winter monsoon variability impacts not only the regional hydrology but also surface water circulation throughout the SCS and Indonesian Seas. Our SSS reconstruction reveals varying influences of the EAWM on surface water circulation pre- and post-1979 resulting from large shifts in the state of Indo-Pacific climate. Such changes likely affect inter-ocean heat exchange, agriculture, and reef ecosystems throughout Southeast Asia and underscore the importance of high-resolution studies that can distinguish seasonal and interannual climate dynamics.

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