What did determine the warming trend in the Indonesian sea?

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Abstract

The Indonesian sea is the only low-latitude pathway connecting two tropical oceans, which plays an important role in the coupled ocean-atmosphere mode in the Indo-Pacific sector. A small change in the sea surface temperature (SST) in the Indonesian sea has a significant influence on the precipitation and air-sea heat flux. During the past 33 years, the SST in the Indonesian sea has indicated a warming trend on the average of 0.19 ± 0.04 decade^{-1}, which is larger than global SST warming trend. Moreover, the warming trend indicates seasonal variations, in which maximum trend occurred during boreal summer season. Investigation on the potential driver for this warming trend, namely, the net surface heat flux, resulted in an opposite trend (cooling trend), while the Ekman pumping and the wind mixing only play a minor role on the SST warming. Here, we proposed the upper layer process associated with an increasing trend in precipitation and decreasing trend in mixed layer depth (MLD) for the SST warming within the Indonesian seas. Shoaling of MLD gives a favorable condition for the surface heat flux to warm the surface ocean. However, shoaling of MLD could not solely explain the total SST warming within the Indonesian seas. The seasonal dependence in the warming trend, highest during boreal summer, was significantly related to the Indo-Pacific climate modes, namely the negative Indian Ocean Dipole (IOD) and La Niña events. Higher warming trend observed in the south of Makassar Strait and in the eastern Indonesian seas, in the vicinity of the Maluku Sea and the northeastern part of the Banda Sea, was significantly associated with the La Niña event. Meanwhile, strong warming trend observed in the Karimata Strait and Java Sea, and in the Flores Sea south of Sulawesi Island seems to be enhanced by the negative IOD event. Our rough quantitative estimate of the possible mechanism leading to the SST warming suggests that other mechanism might be at work in warming the SST within the Indonesian seas. Horizontal heat advection associated with an increasing trend of the heat transport from the Pacific into the Indian Ocean by the Indonesian Throughflow (ITF) might play a role in causing the warming trend within the Indonesian seas. However, to what extend this heat advection could modulate the SST warming is still unresolved in the present study. Further study based on realistic model output as well as long-term observational records is necessary to describe the dynamics underlying the warming trend within the Indonesian seas.

Keywords: Decadal trend, ENSO, Indian Ocean Dipole, Mixed layer depth, Net heat flux, Precipitation, Sea surface temperature

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Introduction

One important parameter for the dynamics of ocean-atmosphere interaction is sea surface temperature (SST). The increasing trend of SST in the tropics may affect natural modes of tropical ocean-atmosphere variability, such as the El Niño—Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) Mode, and their associated climatic impacts (Deser et al. 2009). Previous study has suggested that the Indian Ocean warm pool located west of Sumatra has experienced a significant warming of about 0.7 °C over a period of 1901–2012 (Roxy et al. 2014). Meanwhile, an increase of about 0.5–1 °C in SST of the Indian Ocean from 1960 to 1999 has also been reported (Alory et al. 2007). Secular warming has also been observed in the eastern Indonesian sea near the Timor Island/Savu Sea (Cahyarini et al. 2014). A weakening of upwelling associated with a slowdown of wind-driven Ekman pumping has been linked with this warming trend. Besides, it has also been proposed that changes in the shallow meridional overturning circulation may cause the warming trend in the tropical Indian Ocean (Lee 2004; Schoenefeldt and Schott 2006). A prominent warming trend has also been observed in the Pacific warm pool (Wang and Mehta 2008; Weller et al. 2016). The warming of the Pacific warm pool in recent decades has been suggested to play an important role in regulating decadal variability in the Hadley and Walker circulations.

The Indo-Pacific warm pool, including the Indonesian sea, plays an important role in regulating global climate variations (De Deckker 2016; Sprintall et al. 2014). Note that SST changes of O (1 °C) in the warm pool region may cause a large-scale climate variation. Previous studies have shown that the variability of SST in the Indonesian region may affect rainfall over the Maritime Continent (McBride et al. 2003) and Australia (Nicholls 1984). It was suggested that there is also a robust correlation between SST and precipitation over the Maritime Continent (Dayem et al. 2007). High precipitation rates over the Maritime Continent are associated with high SST in the region. They also found that the strength of the Walker Circulation is related to the precipitation rates over the Maritime Continent. When the precipitation increases, the surface easterlies over the tropical Pacific Ocean are strengthened and thus leading to a stronger Walker Circulation.

Given the importance of SST within the Maritime Continent, it is therefore imperative to have a firm understanding on the dynamics of SST warming within the Indonesian sea. This study, therefore, was designed to evaluate the pattern and magnitude of warming trend within the Indonesian sea and to propose possible mechanism underlying this warming trend.

The paper is organized as follows. The "Data" section describes all observational and reanalysis data used in this study. In the "Observed trend and variability of the SST" section, we present the observed SST, surface heat flux, and surface wind variability. Potential drivers for SST variability within the Indonesian sea are discussed in the "Potential drivers for the observed SST trend" section. The last section is reserved for "Summary and conclusions".

Data

The SST data were obtained from the daily Optimum Interpolated Sea Surface Temperature (OISST) based on the Advanced Very High Resolution Radiometer (AVHRR) from National Oceanographic and Atmospheric Administration (Banzon et al. 2016; Reynolds et al. 2007). The data have uniform spatial resolution of 0.25° × 0.25°. Data for a period of January 1982 to December 2014 are used in this study. Surface heat flux was obtained from the Objectively Analyzed Air-Sea Fluxes (OAFlux) Ver. 3 that has uniform horizontal resolution of 1° × 1° and covers a period of January 1982 to December 2009. The evaporation data from the OAFlux products have been used in previous studies to evaluate the water cycle (Lee et al. 2019) and the fresh water flux (Du et al. 2019) in the Maritime Continent.

We used monthly surface winds stress data from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 for a period of January 1982 to December 2014 that have horizontal resolution of 0.25° × 0.25°. The precipitation data obtained from the CPC Merged Analyzed of Precipitation (CMAP) were also used in this study. The data have spatial resolution of 1° × 1° and cover a period of January 1982–December 2014. Note that the climatological fields for all parameters were calculated for a period of January 1982–December 2014, when all datasets are available. Then, the anomaly fields were defined as the deviation from the climatological fields.

To investigate the possible relationship between the mixed layer dynamics and the SST trend, we first collected available CTD, XCTD, and XBT observations within the Indonesian seas from the World Ocean Database (WOD) 2018 (https://www.nodc.noaa.gov/OC5/WOD/pr_wod.html). We selected nearly repeated observations within the eastern Indonesian region, bounded by 5°S–7°S, 124.5°E–126°E. The mixed layered depth (MLD) is calculated based on the temperature and salinity profiles of this selected WOD dataset. In this study, a density criterion with a density difference of 0.2 kg/m^3 from the surface value is used to define the MLD.

Results and discussion

Observed trend and variability of the SST

Figure 1 illustrates the SST trend observed within the Indonesian sea and its surrounding sea from 1982 to 2014, which indicates significant warming trend. A close examination of the SST trend within the Indonesian sea reveals that the highest warming trend (> 0.2 °C/decade) was observed in the eastern parts (Fig. 1a). This warming trend was highest in the vicinity of Maluku Sea/Molluca

Sea and in the northern part of the Banda Sea as well as in the Flores Sea and the southern part of Makassar Strait.

The area-averaged trend within the Indonesian sea shows a ubiquitous warming trend at a rate of about 0.19° ± 0.04 °C/decade, though there was a short relaxation in early 1990s (Fig. 1b). Superposed on this secular trend is shorter timescale variation. We found that there were two robust events of warming tendency occurring
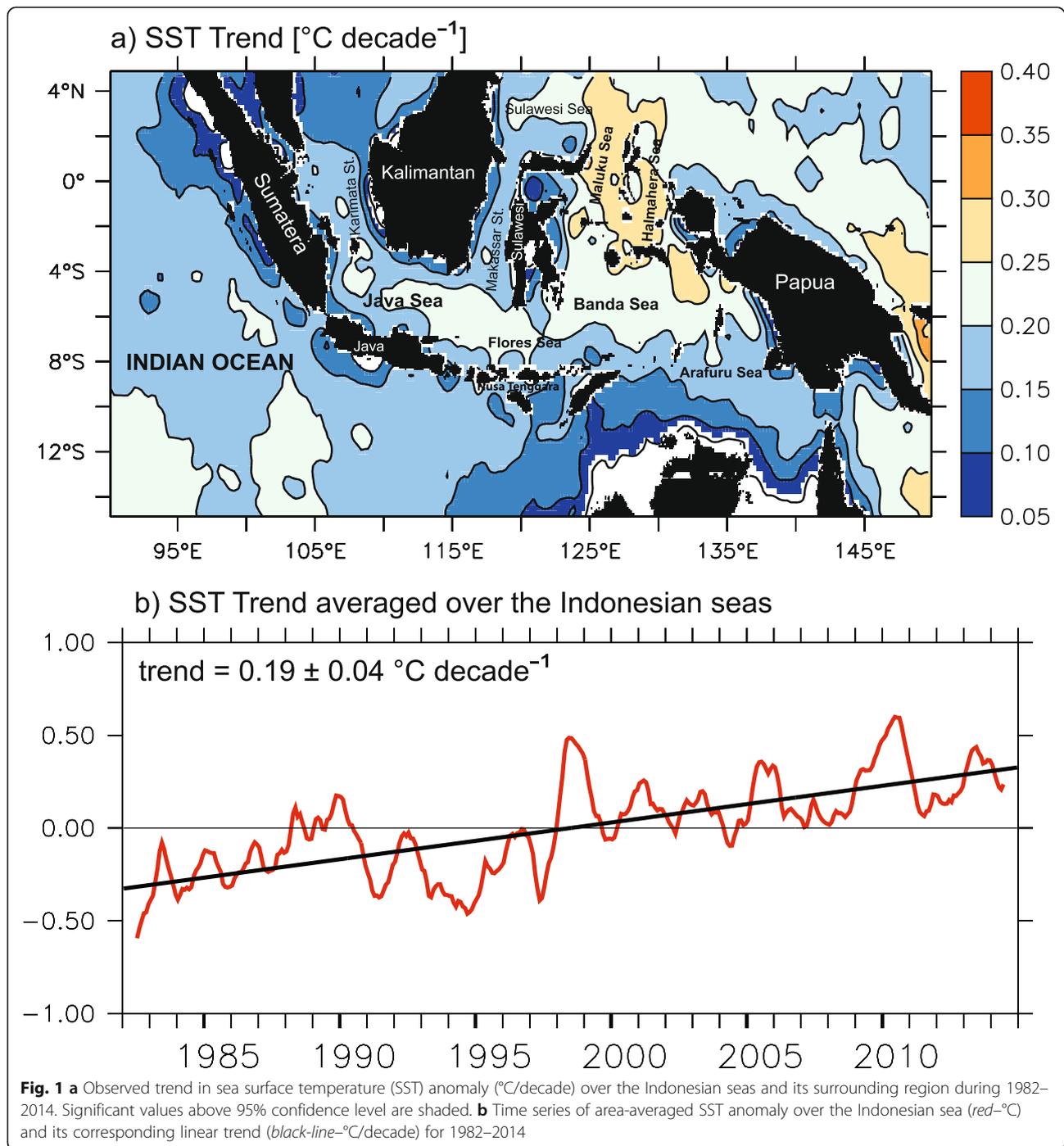
Fig. 1 a Observed trend in sea surface temperature (SST) anomaly (°C/decade) over the Indonesian seas and its surrounding region during 1982–2014. Significant values above 95% confidence level are shaded. **b** Time series of area-averaged SST anomaly over the Indonesian sea (*red*–°C) and its corresponding linear trend (*black-line*–°C/decade) for 1982–2014

during 1998/1999 and 2010/2011. We hypothesize that this robust warming events were associated with the La Niña events that increased precipitation over the Indonesian region (Aldrian and Susanto 2003; Hendrawan et al. 2019; Lee 2015; Lestari et al. 2018; Supari et al. 2018). This possible relationship will be discussed in detail later in the "Results and discussion section".

The secular trend shown in Fig. 1 has seasonal dependence. The seasonal trends of SST anomaly over the Indonesian sea are shown in Fig. 2 for the boreal spring (MAM), summer (JJA), autumn (SON), and winter (DJF), respectively. Summer warming is notably strong in the eastern Indonesian seas, with a significant maximum warming trend in the vicinity of Maluku Sea, Banda Sea, and the southern part of the Makassar Strait (Fig. 2b). The area-averaged SST within the Indonesian seas during the summer season is 0.21° ± 0.03°C/decade, slightly higher than that shown in Fig. 1b.

The warming trend in spring exhibit the lowest in magnitude compared to those observed during other seasons (Fig. 2a). Only the area of Maluku Sea and the southern part of Makassar Strait show slightly higher warming trend compared to other region during this season. Meanwhile, the pattern of warming trend in autumn shows almost similar with that observed in summer (Fig. 2b, c). Remarkable warming trends were observed in the southern part of Makassar Strait, in the

vicinity of Maluku and Halmahera Seas, and in the northeastern part of Banda Sea. However, the magnitude of warming trend was slightly lower during autumn than that during summer. It is notable that the trend in winter season exhibits a slight different pattern compared with other seasons (Fig. 2d). During winter season, high warming trends were observed in the Karimata Strait, the north of Halmahera and the northeastern part of Banda Sea. Meanwhile, the warming rate in the inner Indonesian seas was weaker compared to that observed during other seasons.

Potential drivers for the observed SST trend

It was observed that the Indonesian seas show continuous warming, whereas the warming was very prominent after mid-1990s. Now, the question is what are the physical mechanisms underlying the observed SST trend within the Indonesian sea? We start the analysis by examining the surface heat flux, namely, the net surface heat flux, the Ekman pumping, and the wind mixing. Note that the net surface heat flux is defined as

$$Q_o = Q_{\text{SWR}} + Q_{\text{LWR}} + Q_{\text{LHF}} + Q_{\text{SHF}} \qquad (1)$$

where Q_{SWR} denotes the shortwave radiation, Q_{LWR} is the longwave radiation, Q_{LHF} represents the latent heat
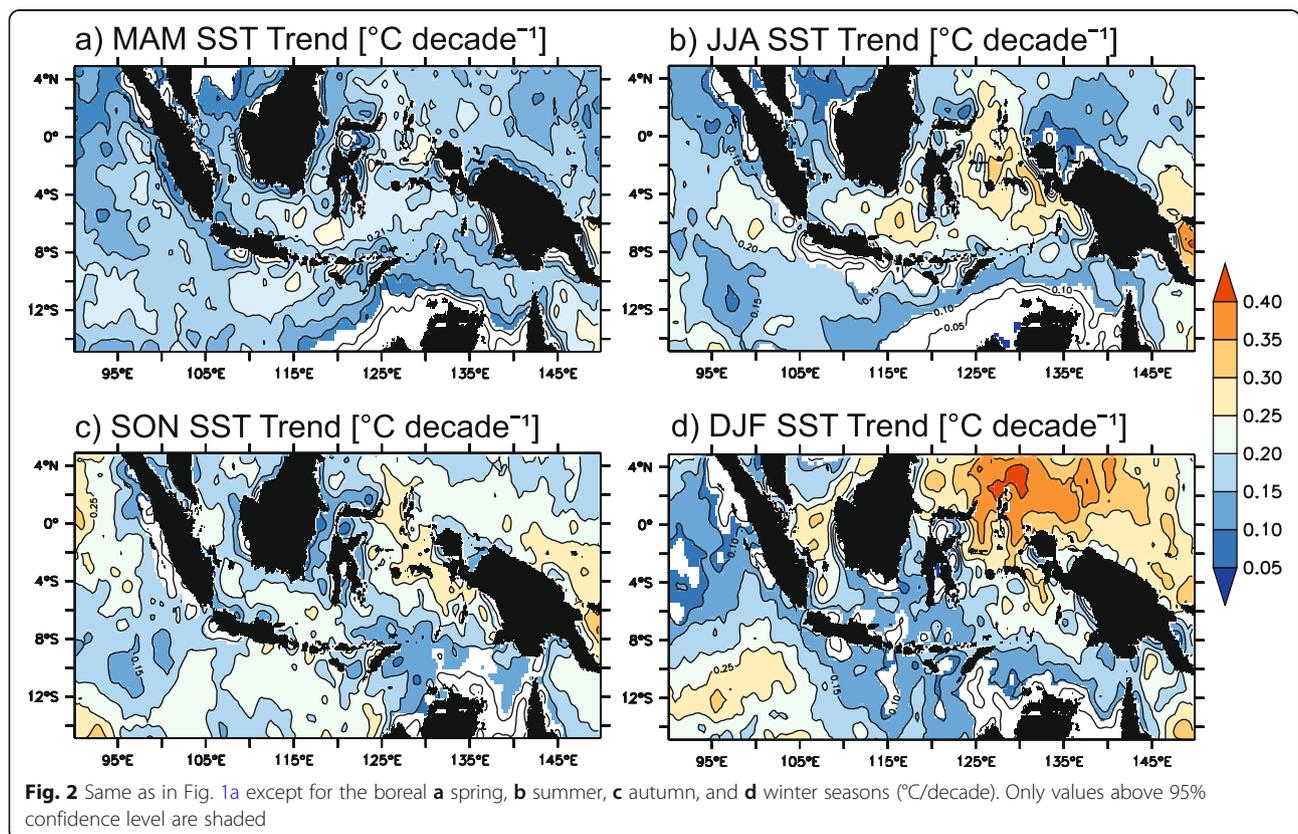
Fig. 2 Same as in Fig. 1a except for the boreal **a** spring, **b** summer, **c** autumn, and **d** winter seasons (°C/decade). Only values above 95% confidence level are shaded

flux, and Q_{SHF} is the sensible heat flux. Meanwhile, the Ekman pumping is calculated following (Gill 1983),

$$w_{ek} = \frac{1}{\rho} \nabla \times \left(\frac{\tau_{\mathrm{wind}}}{f} \right) \qquad (2)$$

where ρ indicates the density of sea water, τ_{wind} is the wind stress, and f denotes the Coriolis force. On the other hand, we also estimate the wind-induced surface ocean mixing which is proportional to the cubed of the wind fields U_*^3 (Ueyama and Monger 2005).

Figure 3 shows the trends of net surface heat flux (Q_{o}), Ekman pumping and wind induced-mixing. It was clearly shown that the Q_{o} reveals significant negative trend over the Maritime Continent, favoring a decrease, not an increase, in SST (Fig. 3a). The decreasing trend distributed almost uniformly across the Maritime Continent with higher negative trends was observed in the vicinity of Maluku Island and Nusa Tenggara Island chain. This suggests that Q_{o} is unlikely to cause the observed SST warming trend within the Indonesian seas.

As the monsoonal winds dominate the atmospheric circulation over the Maritime Continent, seasonal upwelling/downwelling plays significant role on the seasonal variation of SST within the Indonesian sea (Gordon and Susanto 2003). The southeasterly (northwesterly) winds observed during the southeast (northwest) monsoon seasons in JJA (DJF) are favorable for the upwelling (downwelling) within the Indonesian seas. We then examined whether the Ekman pumping plays a role in the SST warming within the Indonesian sea (Fig. 3b). It is shown that there were significant positive trends (upwelling favorable) in the northeastern Banda and Maluku Seas, in the southern part of Java and Flores Seas, and in the southern part of Makassar Strait co-located with the highest warming trend in SST. This positive trend of the Ekman pumping leads to cooling of the SST. Meanwhile, negative trends (downwelling favorable) were observed only in the area south of Kalimantan (northern part of Java Sea and Karimata Strait) and south of Java. Since the Ekman pumping shows opposite trend to the SST warming, in particular, in the area with the highest warming trend, we may then suggest that the Ekman pumping may play a minor role on the warming trend of SST within the Indonesian sea.

Figure 3c shows that the wind induced-mixing is dominated by a positive trend within the Indonesian sea, except in the Makassar Strait and Maluku Sea, which indicates a negative trend. The positive trend in wind-induced mixing means that there is an increase in mixing activities leading to cooling of SST, while negative trend indicates a weakening in mixing that leads to SST warming. Therefore, we may suggest that the wind-induced mixing only play a minor role on the SST

warming within the Indonesian sea, in particular in the Makassar Strait and Maluku Sea where the highest warming trend was observed. These observations suggest that other mechanisms are at work beyond the simple one-dimensional thermodynamic effect of net surface flux and ocean mixing on the SST variations. Thus, what is a possible physical mechanism underlying the SST warming trend within the Indonesian sea?

In this study, we propose a mechanism, i.e., upper layer processes, that may cause the warming trend within the Indonesian seas. This warming trend could be related to the change in the precipitation and thus the MLD. Figure 4a shows trends in precipitation over the Maritime Continent, which shows increasing trends within the Indonesian Seas, though only a small area has significant value above 95% confidence level. The area-averaged trend of the enhanced precipitation is about 0.2 ± 0.06 mm day^{-1}/decade. We noted that the highest positive precipitation trends were observed over the land. However, the area of SST warming still shows positive precipitation trend, namely, in the southern Makassar Strait and in the vicinity of the Maluku and Halmahera seas (see Fig. 1a).
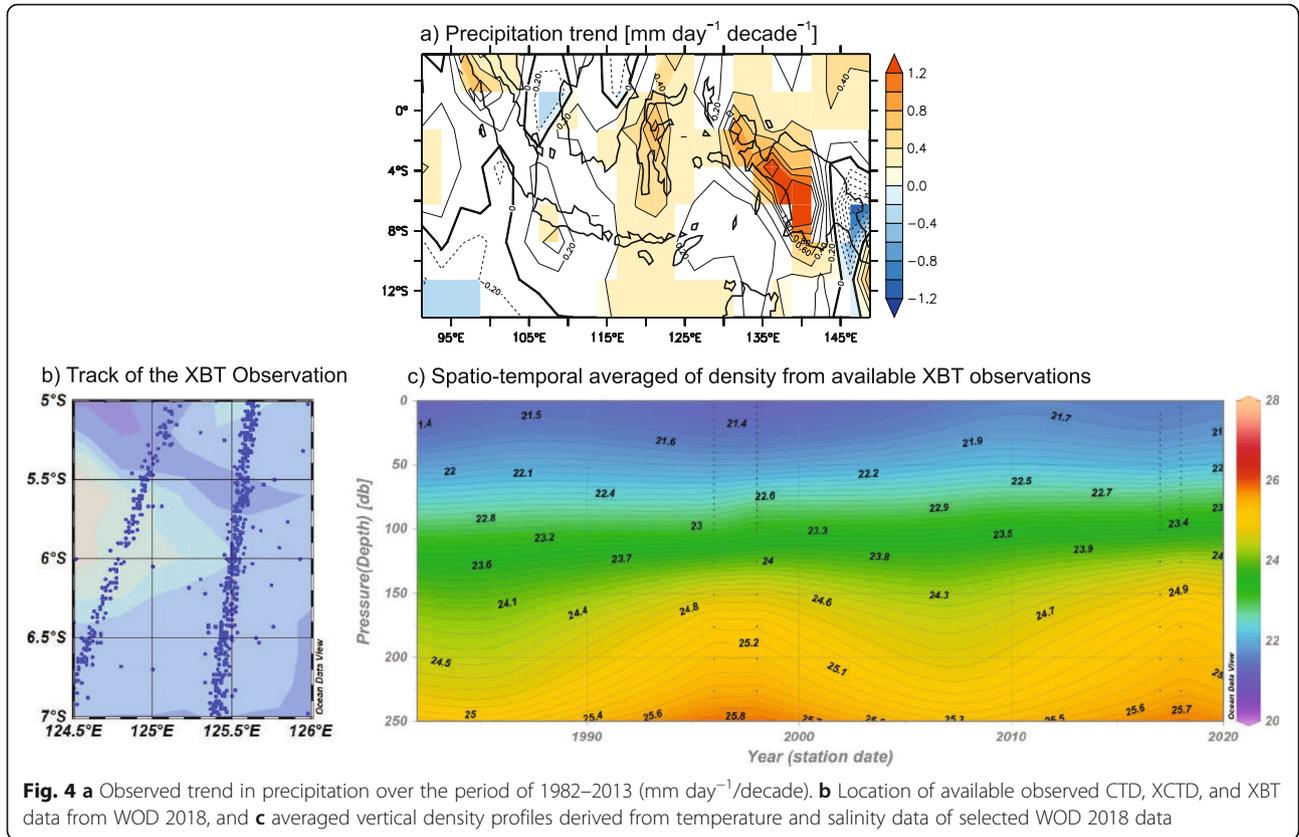
We also calculated the MLD change based on the observed density profiles obtained from the WOD 2018 (Fig. 4c). Note that the density profiles were calculated based on 659 available observations during the period of 1982–2019 within the Indonesian seas (Fig. 4b). The result shows that the MLD within the Indonesian Sea clearly indicates a shoaling trend at a rate of -1.3 ± 0.4 m/decade. It should be noted that the location of MLD shoaling trend is collocated with the area of positive trend in precipitation. We may propose that shoaling of mixed layer depth associated with increasing trend in precipitation give a favorable condition for surface heat flux to warm the ocean. We then roughly estimated the contribution of shoaling MLD to the warming trend within the Indonesian seas using a very simple one-dimensional heat budget calculation. The averaged heat flux over the Indonesian region in the early observation was $Q_{\mathrm{o}} = 92.5$ W m^{-2} and the MLD was $h_{\mathrm{o}} = 25.1$ m. The averaged trend of heat flux (Fig. 3a) was $Q_t = -11.73$ W m^{-2} decade^{-1}. From the mixed layer heat budget, we have

$$\frac{\partial T}{\partial t} = \frac{Q_o + Q_t t}{\rho_o C_p (h_o + h_t t)} + (Advection + Diffussion). \qquad (1)$$

where T is the mixed layer temperature, ρ_{o} is the density of seawater, C_{p} is heat capacity, and Q_{o} and h_{o} are the surface heat flux and MLD at the first year of calculation, respectively. Meanwhile, Q_{t} and h_{t} are the surface
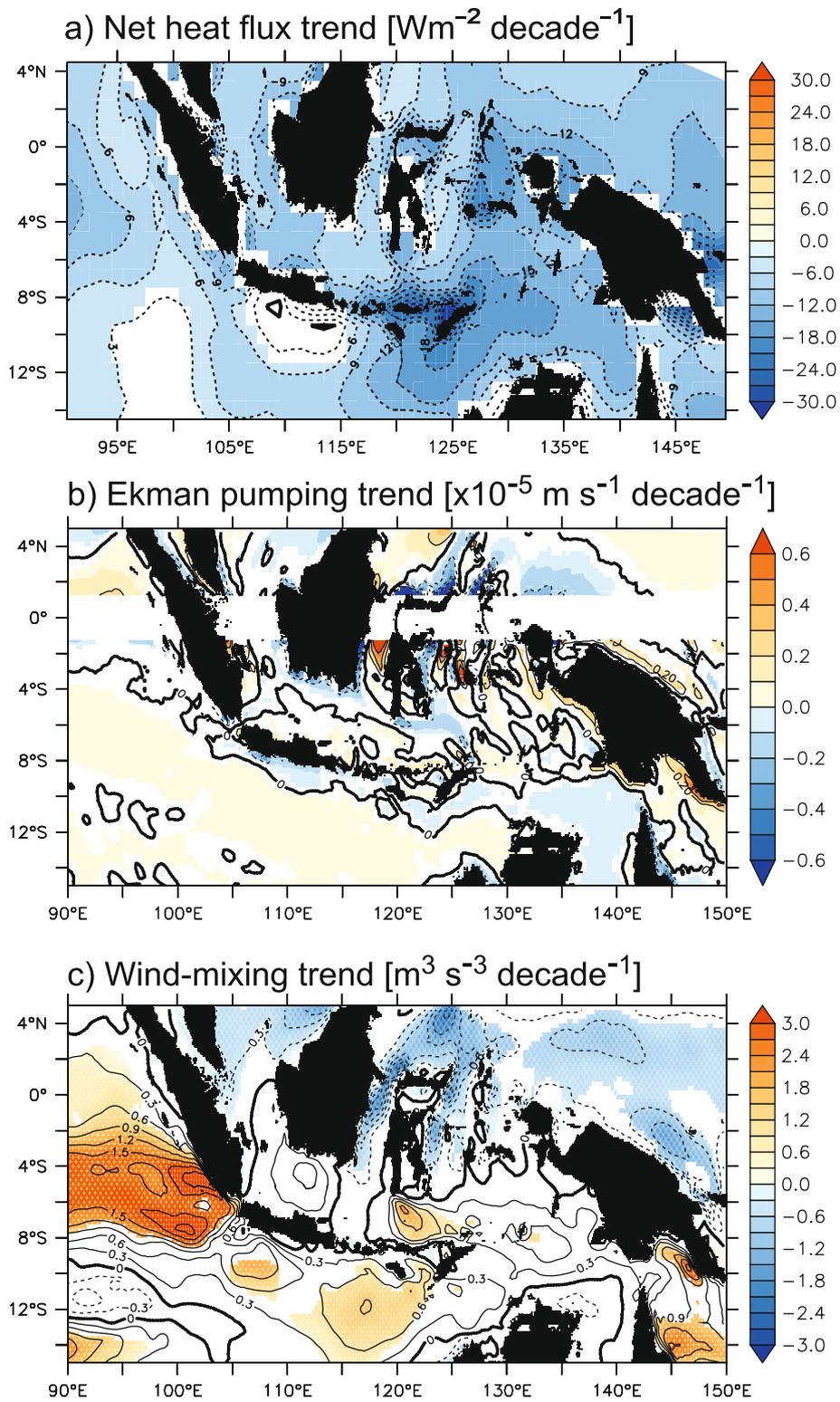
Fig. 3 Observed trend in **a** net surface heat flux (W m^{-2} decade^{-1}) during 1982–2009, **b** Ekman pumping (× 10^{-5} m s^{-1} decade^{-1}), and **c** wind induced-mixing (m^{-3} s^{-3} decade^{-1}) during 1982–2014. Significant values above 95% confidence level are shaded

Fig. 4 a Observed trend in precipitation over the period of 1982–2013 (mm day^{-1}/decade). **b** Location of available observed CTD, XCTD, and XBT data from WOD 2018, and **c** averaged vertical density profiles derived from temperature and salinity data of selected WOD 2018 data

heat flux and MLD trends, respectively. Then, at $t = 0$ we may define:

$$\frac{\partial T}{\partial t} = \frac{Q_o}{\rho_o C_p h_o} + (Advection + Diffusion). \qquad (2)$$

Thus, we may estimate the role of MLD by combining Eq. (1) and (2) as

$$\frac{Q_o}{\rho_o C_p h_o} = \frac{Q_o + Q_t t}{\rho_o C_p (h_o + h_t t)}, \qquad (3)$$

Equation (3) can be simplified as

$$h_t = \frac{Q_t}{Q_o} h_o. \qquad (4)$$

Based on Eq. (4), we may suggest that in order to have SST warming trend at a rate of 0.19 °C/decade, the MLD must be shoaling at a rate of about − 3.17 m/decade. Considering the observed shoaling of MLD was at a rate of − 1.3 ± 0.4 m/decade, we might suggest that MLD shoaling only could not solely explain the SST warming within the Indonesian seas. Our result, though, remained an open question on what other mechanisms play a role in warming the SST within the Indonesian seas.

The Indonesian sea is located in the region of Indonesian Throughflow (ITF), which is considered to play an important role for the heat budget of the Pacific and Indian Oceans. Previous studies have proposed an increasing trend of the ITF transport associated with an increase in precipitation over the Maritime Continent (Hu and Sprintall 2017). They suggested that the increase in precipitation over the Maritime Continent freshened the Indonesian seas thus reinforce the ITF's volume transport leading to an increase of heat transport from Pacific to the Indian Ocean. Enhanced heat transport from the Pacific to the Indian Ocean by the ITF has also been proposed in earlier study (Lee et al. 2015). However, to what extent does the heat advection associated with an increased ITF could modulate the SST within the Indonesian seas at longer time scale is remain an open question. Considering the important role of SST variability within the Indonesian seas to the regional as well as global climate variations, our study may suggest a call for urgent direct and long oceanic observations within the Indonesian seas.

Role of large-scale climate variability
As discussed in the earlier section, the highest warming trend occurred during summer season (Fig. 2b). We noted that the summer season is associated with dry

condition (low precipitation) in Indonesia. The question then arises why the highest warming occurred during low precipitation season. Previous study has shown that the La Niña events significantly enhanced precipitation over the Maritime Continent during summer season (Aldrian and Susanto 2003; Hendrawan et al. 2019; Lestari et al. 2018; Supari et al. 2018). Hence, it is natural to ask how well such modes of climate variability correlate with the observed spatial structure in the SST trend.

Figure 5 shows the normalized JJA DMI and Niño3.4 indices. The DMI has a clear positive trend in 1982–2014 of 0.02 ± 0.08 °C decade^{-1} indicating a trend toward a positive IOD event (Fig. 5a). Meanwhile, the Niño3.4 index has a negative trend − 0.07 ± 0.05 °C decade^{-1} showing that the La Niña events occurred more frequently in later period (Fig. 5b). Both the positive IOD and El Niño events cause SST cooling in the eastern tropical Indian Ocean as well as within the Indonesian sea. The positive IOD event is associated with anomalously strong upwelling along the southern coasts of Java and Sumatra, while during El Niño conditions, the western Pacific is cooler than normal, and the horizontal advection of this colder water may contribute to cooling in the Indonesian sea.

Figure 6 displays the corresponding partial correlation coefficients between JJA SST and the DMI (Fig. 6a) and Niño3.4 (Fig. 6b). Note that, the time series are all detrended prior to the partial correlation analysis. As for the DMI, the SST anomalies exhibit significant negative correlation in the southern coast of Java and Sumatra, in the Karimata Strait and Java Sea, and in the Flores Sea

south of Sulawesi Island (Fig. 6a). However, there was no significant correlation between SST and DMI in the eastern Indonesian seas, in particular in the Maluku and Banda Seas where the highest warming trend were observed. This negative correlation indicates that the positive (negative) IOD caused cooling (warming) of SST in the upper mentioned regions.

On the other hand, the partial correlation between the JJA SST with Niño3.4 index revealed significant negative correlations in the north of the Papua and the Maluku Sea regions, in the northeastern Banda Sea, and in the southern part of Makassar Strait collocated with the highest warming trend (Fig. 6b). Again, this out of phase correlation between the SST and Nino3.4 index suggests the cooling (warming) SST trend observed within the Indonesian seas was induced by El Niño (La Niña) events. A closer examination on the correlation maps and the SST trends, it was found that La Niña event contributed to the warming trend in the south of Makassar Strait as well as in the eastern Indonesian seas, in the vicinity of Maluku Strait and in the northeastern part of the Banda Sea (Figs. 1a and 6b).

Summary and conclusions

In this study, we have examined the warming trend in SST within the Indonesian sea using available observational data. Our analysis reveals that during the past 33 years (1982–2014), the SST in the Indonesian sea experienced a warming trend on the average of 0.19 ± 0.04 °C/decade, which is larger than global SST warming trend of 0.07 °C/decade (Wang and Mehta 2008). It was noted
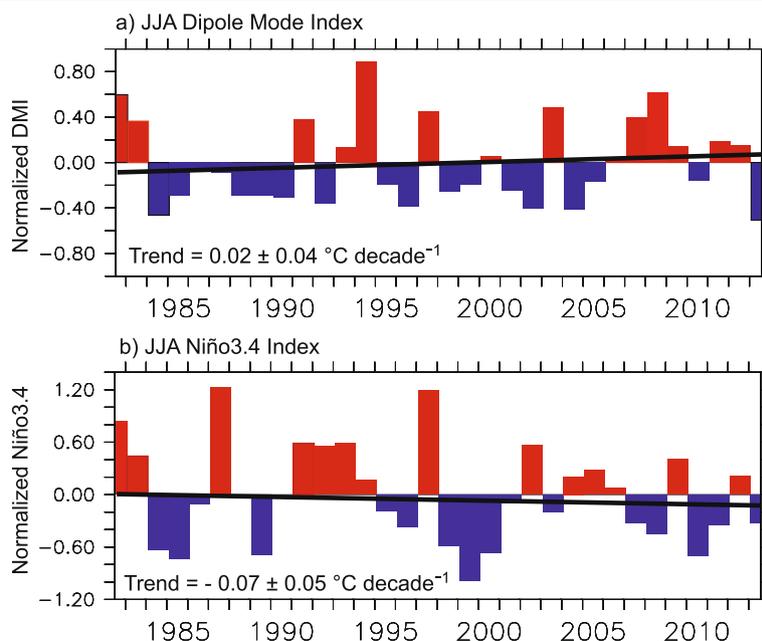
Fig. 5 Normalized **a** Dipole Mode Index, and **b** Niño3.4 index during JJA season
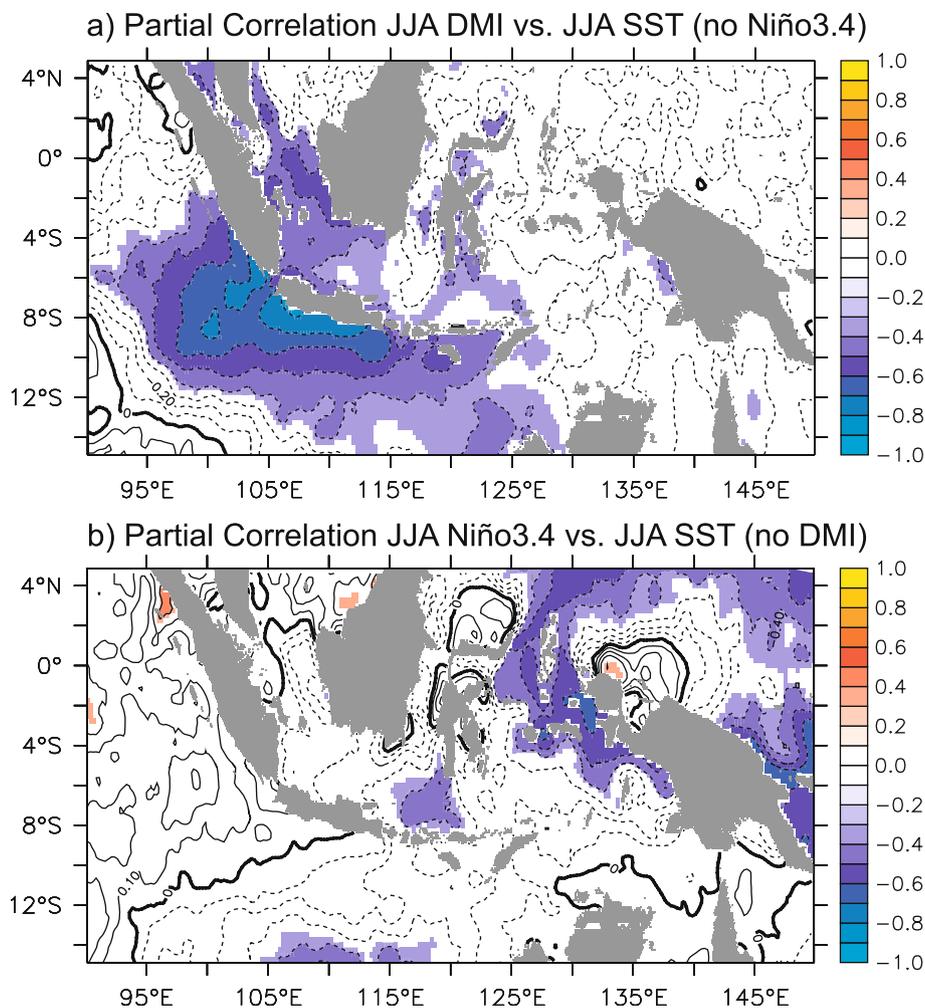
Fig. 6 Partial correlation coefficient between JJA SST and **a** Dipole Mode Index, and **b** Niño3.4 index. Values above 95% confidence level are shaded

that the eastern Indonesian sea regions (i.e., in the vicinity of Maluku Sea, the northeastern part of Banda Sea, and the southern part of Makassar Strait) experienced stronger warming trend compared to the other regions within the Indonesian seas (Fig. 1a). Moreover, the warming trend indicates seasonal dependence, in which maximum trend occurred during boreal summer (Fig. 2b), while the minimum trend was observed during boreal winter (Fig. 2d).

Investigation on the driving mechanism of this SST warming trend revealed that the net surface heat flux revealed a cooling trend (Fig. 3a), while the Ekman pumping and wind mixing also only play a minor role to the warming trend in the SST (Fig. 3b, c). It suggests that other mechanisms may contribute to the warming trend within the Indonesian seas. In this study, we proposed a mechanism, in which the upper layer processes are responsible for the warming trend

within the Indonesian seas. We found an increasing trend in precipitation over the Indonesian regions as previously suggested (Hu and Sprintall 2017). The increase in precipitation has caused a gradual decrease in the MLD. We suggest that shoaling of MLD gives a favorable condition for the surface heat flux to warm the surface ocean. This proposed mechanism, however, also could not solely explain the warming trend within the Indonesian region. In addition, we also suggest that the highest warming trend observed in summer was significantly correlated with the large-scale climate modes in the Indo-Pacific sector, namely, the negative IOD and La Niña events. Partial correlation analysis revealed that negative IOD event contributed to the warming trend observed in the Karimata Strait Strait and Java Sea, and in the Flores Sea south of Sulawesi Island (Figs. 1a and 6a, b). Meanwhile, observed warming trend in the eastern

Indonesian seas and in the southern part of Makassar Strait was significantly induced by the La Niña events.

Our rough quantitative estimate on the mechanism causing a warming trend within the Indonesian seas suggests that there are other mechanisms responsible for this warming trend. One potential driver is heat advection associated with the heat transport by the ITF. It was suggested that there was an increasing trend of heat transport from the Pacific into the Indian Ocean by the ITF (Hu and Sprintall 2017; Lee et al. 2015). However, to what extend does this heat advection induce warming trend within the Indonesian seas is still unresolved in the present study. A complex topography and high tidal mixing within the Indonesian seas make it difficult to estimate the warming trend based on the model outputs as they may not reproduce a correct SST within the Indonesian seas. Therefore, we may suggest a call for urgent direct and long oceanic observations within the Indonesian seas for a better understanding of the SST variability in hotspot of the climate study.

Abbreviations
AVHRR: Advanced Very High-Resolution Radiometer; CMAP: CPC Merged Analyzed of Precipitation; CTD: Conductivity-temperature depth; ECMWF: European Centre for Medium-Range Weather Forecasts; OAFlux: Objectively Analyzed Air-Sea Fluxes; OISST: Optimum Interpolated Sea Surface Temperature; WOD: World Ocean Database; XBT: Expendable Bathy Thermographs; XCTD: Expendable Conductivity-Temperature Depth

Authors' contributions
II proposed the topic, designed the study, wrote the original draft. WM and DL analyzed the data and helped in the interpretation and visualization. YM collaborated with the corresponding author in the construction of manuscript, writing review, and editing. All authors read and approved the final manuscript.

Availability of data and materials
The SST data are available in the https://www.ncdc.noaa.gov/oisst. The surface heat flux data are obtained from the http://www.oaflux.whoi.edu. The surface wind stress is available at http://apdrc.soest.hawaii.edu/. The precipitation data are provided at https://www.esrl.noaa.gov/psd/data/gridded/data.cmap.html. Meanwhile, the XBT data are obtained from the World Ocean Database 2018 and available at https://www.nodc.noaa.gov/OC5/WOD/pr_wod.html.

Competing interests
The authors declare that they have no competing interests.

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