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Coral based-ENSO/IOD related climate variability in Indonesia: a review

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Abstract. Indonesia is located in the prominent site to study climate variability as it lies between Pacific and Indian Ocean. It has consequences to the regional climate in Indonesia that its climate variability is influenced by the climate events in the Pacific oceans (e.g. ENSO) and in the Indian ocean (e.g. IOD), and monsoon as well as Indonesian Throughflow (ITF). Northwestern monsoon causes rainfall in the region of Indonesia, while reversely Southwestern monsoon causes dry season around Indonesia. The ENSO warm phase called El Nino causes several droughts in Indonesian region, reversely the La Nina causes flooding in some regions in Indonesia. However, the impact of ENSO in Indonesia is different from one place to the others. Having better understanding on the climate phenomenon and its impact to the region requires long time series climate data. Paleoclimate study which provides climate data back into hundreds to thousands even to million years overcome this requirement. Coral Sr/Ca can provide information on past sea surface temperature (SST) and paired Sr/Ca and $\delta^{18}O$ may be used to reconstruct variations in the precipitation balance (salinity) at monthly to annual interannual resolution. Several climate studies based on coral geochemical records in Indonesia show that coral Sr/Ca and $\delta^{18}O$ from Indonesian records SST and salinity respectively. Coral Sr/Ca from inshore Seribu islands complex shows more air temperature rather than SST. Modern coral from Timor shows the impact of ENSO and IOD to the saliniy and SST is different at Timor sea. This result should be taken into account when interpreting Paleoclimate records over Indonesia. Timor coral also shows more pronounced low frequency SST variability compared to the SST reanalysis (model). The longer data of low frequency variability will improve the understanding of warming trend in this climatically important region.

1. Introduction

The El Nino Southern Oscillation (ENSO) is defined as the sea surface temperature anomaly gradient between eastern and western Pacific basin. Meanwhile, the Indian Ocean is defined as SST anomaly gradient between eastern and western Indian Ocean. Indonesia links to the Pacific and Indian Ocean, thus the climate in the Indonesia region is related to the climate events in both Pacific and Indian oceans, which is what so-called West Pacific Warm Pool (which actually extends into the eastern Indian Ocean; e.g. [1].

These climate events, ENSO and IOD, cause drought during El Nino (warm ENSO phase) and positive IOD and cause floods in the eastern Pacific coastal cities. Reversely, La Nina (cold ENSO phase) and negative IOD bring much rainfall which leads to flooding in the region of Indonesia and surrounding countries. These may lead to severe economic consequence to the countries around the world. ENSO/IOD response to global warming is uncertain, as the instrumental data record is not sufficient to understand these events [2,3]. This requires long time series data of climate parameter which can be covered by proxy data [3] e.g. coral, sediment, tree ring etc. In Indonesia ENSO/IOD

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strongly influence precipitation across the region, and the correlation is different from one place to another [4]. However, how the ENSO/IOD impact to the local climate variability in Indonesia remains in questions.

Geochemical proxies i.e Sr/Ca ad δ^{18}O in corals have been used for reconstructing past climate variability. Coral Sr/Ca can provide information on past SST [5,6] and paired Sr/Ca and δ^{18}O may be used to reconstruct variations in the precipitation balance (salinity) at monthly resolution [5,7]. In this paper, several results of the study of climate reconstruction using geochemical proxies recorded in coral from Indonesian waters will be summarized and evaluated.

2. SST/Salinity reconstruction based on coral records in Indonesia

Several researches have demonstrated that salinity changes at Timor (an exit passage where low salinity water from the Banda Sea enters the Indian Ocean) can be reconstructed from paired Sr/Ca and δ^{18}O measurements in a Timor coral [5,8]. However, the method of δ^{18}O seawater reconstruction (which is further used to reconstruct salinity) using coral proxies is still in debate. [5] propose the new method of salinity /δ^{18}O seawater reconstruction using coral proxies i.e the centering method. The centering method uses centered proxy and subtracts the thermal component inferred from coral Sr/Ca from coral δ^{18}O coral. The residual is a record of δ^{18}O seawater variations. Compared to the previous method i.e [7], the centering method is simpler and has less error propagation. With the centering method, the intercept of the regression equation of coral δ^{18}O (Sr/Ca) and SST is omitted and the known slope of the coral δ^{18}O (Sr/Ca) -SST relationship can be used in the calculation. A second important aspect of this paper is the error calculation of δ^{18}O seawater. It was shown that at some locations the magnitude of seasonal variations of δ^{18}O seawater (salinity) is less than the error of the δ^{18}O seawater reconstruction. That means, it is impossible to resolve seasonal δ^{18}O seawater (salinity) in that location. At sites where δ^{18}O seawater variations are large (which is the case at Indonesian sites, for example) the magnitude of seasonal δ^{18}O seawater variations is larger than the analytical error, and it is possible to do a seasonally resolved δ^{18}O seawater/salinity reconstruction. Therefore, another important scientific contribution from this study is that it provides guidelines for the site selection for δ^{18}O seawater/salinity reconstructions. However, ideally one should use multivariate regression approach of proxy SST regression (e.g [9]) to reconstruct salinity/precipitation. This will require long time monitoring of δ^{18}O seawater or salinity which may consume much time and fund.

Cahyarini et al [8] use the centering method to reconstruct the salinity in the Indonesian Through flow exit passage based on proxy records from Timor coral. Indonesian Through flow (ITF), representing global ocean circulation moving water mass from Pacific to Indian Ocean, strongly influences the Indo-Pacific climate. Monitoring ITF using mooring buoys has been done since 1990 e.g INSTANT project [10] and has provided seasonal and inter-annual timescale data. However, the available data of salinity and SST are sparse (e.g. [10],[11]) and the absence of longer time series data limits the understanding of ITF evolution over the past century. Coral geochemical proxies study overcomes this problem. Timor record is the first longer record (1914-2004) pairing δ^{18}O and Sr/Ca which are available from Indonesia coral. This study convinces us that there is varying imprints of Indo-Pacific climate mode on SST and SSS over the Indonesian maritime region as it is found in Timor corals. Based on Timor coral SST and SSS reconstruction, it shows that Indian Ocean Dipole (IOD) influences SST and SSS while ENSO only influences SST. This result should be taken into account when interpreting Paleoclimate records over Indonesia. This coral also shows more pronounced low frequency SST variability compared to the SST reanalysis (model). The longer data of low frequency variability will improve the understanding of warming trend in this climatically important region.

Coral Sr/Ca from the inshore and offshore Seribu islands waters is used to reconstruct sea surface temperature (SST) and air temperature (Figure 1) [6]. This study shows that the offshore coral shows sea surface temperature proxy better than the inshore coral. Meanwhile, the inshore coral shows air temperature proxy better than the offshore coral. SST across Seribu islands shows high correlation with south east Indian ocean index i.e. the temperature anomaly gradient between south eastern and western Indian ocean, which depicts the influence of Indian ocean dipole event. This means that the SST from

Seribu islands is strongly influenced by the changing temperature in the south eastern Indian ocean. The climate variability across Indonesia seems different from place to place inside Indonesian seas. Therefore, the proxy locations for paleoclimate study in Indonesia need to be chosen carefully.

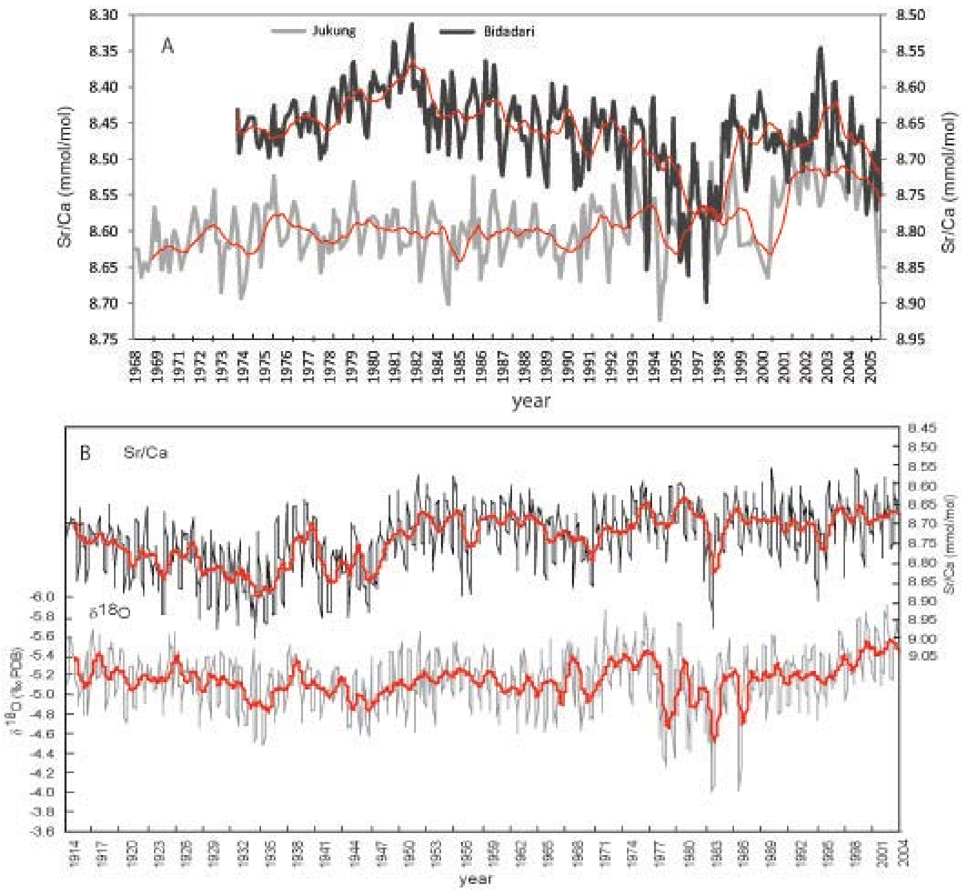

Figure 1. Coral Sr/Ca records from Jukung and Bidadari island represent offshore and inshore coral respectively from the Seribu islands complex (figure modified from [6]). B. Paired coral Sr/Ca and $\delta^{18}O$ from Timor coral (figure modified from [8]). The red line is 12 points running average.

3. Conclusions

To have better understanding on the climate events e.g. ENSO, IOD and their influence to the climate in the tropical maritime region, coral proxy records (i.e. multicores, multi proxies) from many other locations in Indonesia from modern coral (including fossil coral records for longer time period) are still required. $\delta^{18}O$ seawater reconstruction which is further used to reconstruct salinity from paired Sr/Ca and $\delta^{18}O$ content in coral and calibration of coral proxies-temperature need to be improved, and this requires long time series of local data measurement through monitoring oceanography parameters.

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