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Coral Sr/Ca-based Sea Surface Temperature and Air Temperature variability from the inshore and offshore corals in the Seribu Islands, Indonesia

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Abstract

The ability of massive *Porites* corals to faithfully record temperature is assessed. *Porites* corals from Kepulauan Seribu were sampled from one inshore and one offshore site and analyzed for their Sr/Ca variation. The results show that Sr/Ca of the offshore coral tracked SST, while Sr/Ca variation of the inshore coral tracked ambient air temperature. In particular, the inshore SST variation is related to air temperature anomalies of the urban center of Jakarta. The latter we relate to air-sea interactions modifying inshore SST associated with the land-sea breeze mechanism and/or monsoonal circulation. The correlation pattern of monthly coral Sr/Ca with the Niño3.4 index and SEIO-SST reveals that corals in the Seribu islands region respond differently to remote forcing. An opposite response is observed for inshore and offshore corals in response to El Niño onset, yet similar to El Niño mature phase (December to February). SEIO SSTs co-vary strongly with SST and air temperature variability across the Seribu island reef complex. The results of this study clearly indicate that locations of coral proxy records in Indonesia need to be chosen carefully in order to identify the seasonal climate response to local and remote climate and anthropogenic forcing.

Keyword: Coral, Sr/Ca, Sea Surface Temperature, Air Temperature, Indonesia

1. Introduction

The Seribu islands archipelago (also know as Thousand Islands or Kepulauan Seribu in Indonesian) is an archipelago that extends from the bay of Jakarta, a city of over 10 million inhabitants, to more than 80 km to the northwest in the Java sea. A popular tourist destination, the archipelago includes one of the first officially protected marine areas in Indonesia (Salm et al. 1982). The proximity of the Seribu Islands reef complex to Jakarta metropolitan city induced serious environmental problems, for example many of the inshore reefs, that were still thriving in the 1920's (Umbgrove and Verwey, 1929), are now effectively moribund, consisting of little else than sand, turf algae and the odd massive coral (Rachello-Dolmen and Cleary 2007, Cleary et al. 2008, de Voogd and Cleary 2008). Offshore the situation is better, but even here there has been a marked decline in coral cover over the last few decades (Cleary et al. 2008). The Seribu islands are an interesting area to study the influence of large urban populations on reef communities and coastal waters because they are one of the few coral reef systems which are located close to a metropolitan city. Hence, the impact of a large-scale disturbance gradient (e.g. natural factor: El Niño-Southern Oscillation, Monsoon) on coral health in the Jakarta Bay and Seribu islands can be compared with its local-scale disturbance (e.g anthropogenic factors).

A number of recent studies have assessed on-to-offshore variation in environmental conditions and biota of the Seribu islands (Cleary et al., 2006; van der Meij et al. 2009). In addition to this, museum collections, dating back to 1920´s, were used to compare mollusc and coral composition over an eighty year period (van der Meij et al. 2009, 2010).

Coral cores have been used to monitor changes in environmental conditions over long periods of time, importantly extending beyond the onset of the instrumental data collection (e.g.; Linsley et al., 2000; Zinke et al., 2004; Ourbak et al., 2006; Cahyarini et al., 2014). In the Seribu islands, coral cores have previously been used to compare fluorescence banding and Pb concentrations. Scoffin et al. (1989) concluded that fluorescence banding was brighter in inshore than in offshore corals. Inoue et al. (2006) presented five years of Pb concentrations which were shown to increase from the off- to inshore corals.

In addition to the above, corals can also be used to monitor variation in temperature.

Coral Sr/Ca is presently the most promising sea surface temperature proxy in paleoclimatology. Several studies have shown that Sr/Ca is influenced only by sea surface temperature (SST; e.g., Zinke et al. 2004; Corrége 2006; Hetzinger et al. 2006, Cahyarini et al. 2009).

In the present study Sr/Ca ratios in coral cores were determined from massive *Porites* corals in order to reconstruct variations in SST from an inshore and offshore coral reef. Comparing corals from inshore and offshore environments allows us to ascertain to what extent nearshore conditions influence environmental variables such as temperature. We hypothesise that inshore corals are influenced by air temperature over the adjacent land through air-sea interaction while the offshore corals provide truer records of open sea conditions. In addition to this, we will also assess whether there is evidence of a link between the temperature variations at the Seribu islands and remote climate forcing, i.e. El Niño-Southern Oscillation (ENSO) events and/or South Eastern Indian Ocean (SEIO) SST.

2. Climate setting at the Seribu islands reef complex

The Seribu islands reef complex (Figure 1) extends from Jakarta Bay more than 80 km to the northwest in the Java Sea. Natural factors such as the Asian monsoon, ENSO and Indian Ocean Dipole (IOD) influence the waters surrounding the Seribu islands (Haylock and McBride 2001; Aldrian and Susanto 2003; Aldrian and Djamil 2008). During El Nino years, the August SST anomaly shows colder temperature over the Indonesia region including the Seribu Islands than the eastern Pacific Ocean, as exemplified for 2015

(Figure 1). The seasonal movement of freshwater from the South China Sea to the Java sea steered by the monsoonal climate controls seasonal changes of sea surface temperature (SST) and salinity in the Java Sea, and thus influences the Seribu islands waters (Gordon et al. 2004). During the wet season, intensive rainfall feeds freshwater runoff into Jakarta bay. The prevailing monsoon winds distribute the freshwater plume within Jakarta bay affecting the Seribu reef complex with varying intensity. In addition to this, El Niño events cause droughts and have led to recorded warmer sea surface temperature anomalies in several locations across the Seribu islands (Brown and Suharsono 1990; Suharsono 1998). Based on monthly average SST data taken from ERSST data for period of 1992-2005, SST shows two peaks (April and October) and two troughs (August and January). Maximum SST is observed in April (29.81^{o}C) and the minimum (28.63^{o}C) in January (Figure 2). The absolute maxima (May; 28.54^{o}C) and minima (January; 27.06^{o}C) of air temperature at Jakarta are in-phase with ERSST, while the secondary maxima (September) and minima (July) occur 1-2 month earlier. Air temperature follows solar radiation as expected, with similar bimodal seasonal cycle (Figure 2d).

3. Material and Methods

For this pilot study, historical data including sea surface temperature (SST) and Air temperature (AirT) were used for calibration. SST data was obtained from the Extended Reconstructed Sea Surface Temperature (ERSST) database version 2 (Smith et al. 2008). The ERSST dataset is available for the period 1854 till present. In this study, the average ERSST data (further mentioned as SST) for the coordinates of 105^{o} E -106^{o} E, 5 ^{o}S -6 ^{o}S is used. Local measurements of AirT from the Jakarta weather station Ciledug were available for the period June 1992 to September 2005. The Ciledug air temperature data were obtained from the *Badan Meteorologi, Klimatologi, dan Geofisika (*BMKG). Ciledug station is aproximately 30 km to Bidadari Island and 50 km to Jukung Island. Figure 2 shows the seasonality in SST, AirT and coral Sr/Ca.

3.1 Coral sampling and preparation

Massive *Porites* coral cores were drilled in September 2005 in the Seribu islands reef complex, namely at Bidadari, the 'inshore' site at S 6º01'55", E 106º44'47" and Jukung, the 'offshore' site at S 5º34'01", E 106º31'38" (Figure 1). The Bidadari core (code BI) is 68 cm in length and was drilled at 3 m depth. The Jukung (JU) core is 2.23 m in length and was drilled at 2 m depth. A pneumatic drill powered by scuba air pressure was used. The drill bit is a diamond-tipped steel tube 4 cm in diameter and 30 cm long. By using extension rods of 1 m length, it is possible to recover cores of up to 5 m in length (Heiss and Dullo 1997).

Coral cores were cut in two halves and subsequently sectioned to a thickness of 7 mm. Slabs were rinsed several times in an ultrasonic bath for about 15 minutes and dried with compressed air after each step. The clean slabs were dried overnight at 40˚C and X-rayed using 35 kvp for 12 minutes to reveal the annual banding. Slabs were subsampled manually using a hand-held drill with a drilling bit of 1 mm along the growth axis at ± 1 mm intervals to get a monthly resolution. For this study, the Sr/Ca ratio for the Bidadari core and the core top of Jukung core (1.48 m) were analyzed. The X-Rays of the coral slabs and the transect lines for geochemical sampling are provided in the supplementary data 1, 2.

Sr/Ca ratios were measured in an inductively coupled plasma optical emission spectro-photometer (SPECTRO CIROS ICP-OES) at the Geological Institute of the University of

Kiel following a combination of the techniques described in detail by Schrag (1999) and de Villiers et al. (2002). First, 0.5 mg of coral powder was dissolved in 1 ml HNO_3 2%. The working solutions were then prepared by a serial dilution of the sample solution with HNO_3 2% to get a concentration of about 8 ppm Ca. Finally, the standard solution was prepared by dilution of 1ml from a stock solution (0.52 gram of coral powder from a Mayotte coral in 250 ml HNO_3 2% with 2 ml HNO_3 2%). The relative standard deviation (RSD) of multiple measurements on the same day and on different days was about ± 0.15%.

3.2 Chronology

The preliminary chronology was developed using the annual density banding observed in the X-Ray's. SST is proposed to agree with SST at the offshore coral site, while airT is proposed to be a better recorder of SST near the inshore coral site. Assuming that measured airT data are less effected by errors due to undersampling SST near coastal regions as in reanalysis or model data, we used maxima and minima value of measured-air temperature rather than SST (ERSST) for absolute chronology development in this study. A monthly resolved time series using the anchor point method was applied by assigning the minima and maxima in coral Sr/Ca to maxima (May) and minima (January) in AirT in the Seribu island waters. The uncertainty of the chronology development based on the anchor point method is about 1-2 months in any given year (e.g Cahyarini et al. 2009). For the Bidadari coral, we obtained a time window covering July 1973 to September 2005 and the core top of the Jukung coral covered May 1968 to September 2005 (Figure 2). Coral Sr/Ca from both locations Jukung and Bidadari are subsequently calibrated to SST and air T data using linear regression (e.g. Cahyarini et al. 2009;2010)

3.3 Analyses

The reconstructed SST based on coral Sr/Ca (Sr/CaSST) is calculated based on the calibration with gridded SST (e.g Corrège et al., 2004; Felis et al., 2004). Ideally, one should use *in-situ* SST data directly measured from the site where the coral grew. Yet, the limited local SST measurements available have forced most studies to use grid-SST from various sources (Corrège et al., 2004; Cahyarini et al., 2009). However, grid-SST or satellite products do not represent SST well near the coastal regions (Castillo and Lima, 2010). Therefore, we used AirT from Jakarta *Ciledug* station as an independent dataset due to its close proximity to the inshore coral site.

Linear least squares regression between monthly variation of Sr/Ca and SST was used to calibrate Sr/Ca with SST and AirT (Cahyarini et al., 2009; 2010). This approach is commonly used to quantify coral Sr/Ca - SST relationships (e.g Juillet-Leclerc and Schmidt, 2001; Gagan et al., 2000; Linsley et al., 2000, 2004). The shortest available time series is AirT, i.e. 1992-2005, consequently this period of 1992-2005 was chosen as the calibration period between coral Sr/Ca and ERSST/AirT to ensure consistency.

The influence of global climate events, such as ENSO or (SEIO) events, on the coral proxy records is analysed using a statistical time series analysis developed by Oldenborh & Burgers (2005) (http://climexp.knmi.nl/), i.e., correlating time series by taking 3 month running averages. In this study the period of 1992-2005 (period of AirT coverage) was used for calibration and correlation between proxy/historical SST (Air temperature) and the ENSO index to obtain the relationship between proxy/historical SST (Air temperature) and ENSO. We also tested for a relationship with SEIO-SST.

4. Results and Discussion

4.1 Monthly and mean annual coral Sr/Ca – SST calibration

Calibration of coral Sr/Ca with SST/AirT has been based on linear regression between proxy and historical SST datasets. There was a significant linear relationship on monthly time scales between Sr/Ca and SST for the Jukung ($r= 0.53$, regression slope = -0.05, $p< 0.0001$) and Bidadari ($r=0.26$, regression slope = -0.03, $p< 0.0001$) cores for the 1992-2005 calibration period (see detail calibration in Cahyarini & Zinke, 2009; 2010). The slope of the regression for Jukung (but not Bidadari) agreed with published relationships for *Porites* corals, i.e -0.04 to -0.08 mmol/mol/°C (Corrége, 2006). In contrast to the above, on monthly time scales the relationship between Sr/Ca and AirT is stronger for Bidadari ($R= 0.51$, regression slope=-0.043, $p< 0.0001$) (Cahyarini & Zinke, 2009) than Jukung ($R=0.39$, regression slope= -0.03, $p< 0.0001$) (Cahyarini & Zinke, 2010). On annual mean time scales the correlation between Jukung Sr/Ca and SST ($R=0.37$, regression slope = -0.04, $p< 0.0001$) is also stronger than between Bidadari Sr/Ca and SST ($R= 0.2$, regression slope = 0.03, $p< 0.0001$). These results for the annual mean Bidadari coral Sr/Ca are similar to those obtained on monthly time scales.

4.2 Seasonal variation

The monthly mean of SST and AirT was compared with that of coral Sr/Ca for the period 1992 to 2005. All data were standardized to unit variance. The results show that Sr/Ca records SST and air temperature in both corals to varying degrees (Figure 3). Jukung Sr/Ca seasonal variations reflect SST better than AirT, while the opposite holds for Bidadari Sr/Ca. This confirms the calibration results between Sr/Ca and SST (AirT). The seasonal cycle in SST and AirT with two maxima and minima is well represented in both corals. Amplitude and timing of the major temperature changes is correctly displayed. The difference between minimum and maximum (winter/summer) ERSST in the Seribu islands waters is about 1.18±0.4^{o}C, while for AirT it is about 1.40±0.44^{o}C. Sr/Ca from Jukung and Bidadari corals show differences of 0.072±0.021 mmol/mol and 0.069±0.018 mmol/mol, respectively. The changes of Sr/Ca converted to SST result in an average summer/winter SST difference of 1.4^{o}C, following our Sr/Ca-SST relationship of -0.05 mmol/mol/^{o}C for the Jukung coral. This is well within the range of the observed seasonal differences.

4.3 Long-term trend and inter-annual variability

Instrumental SST and AirT both revealed an increase in temperature since the early 1990s with the increase in AirT much more pronounced than SST (Figure 2). The mid-1990s were characterized by relatively cool AirT in comparison to SST. Our Sr/Ca time series from the inshore coral, which appears to closely track AirT, indicates that SST rose between 1973-1980, reached a plateau in the early 1980s followed by a long-term cooling trend which culminated in the mid-1990s (Figure 2). Since 1990, the Bidadari coral indicates increasing SST in agreement with AirT (see supplementary data 4). The interannual variability increased in the most recent period. The offshore coral from Jukung indicates that SST remained relatively constant between 1968 and 1988 followed by an increase until 2005 (Figure 2). The period 1988 to 2005 was characterized by pronounced interannual variations in SST, which were rarely observed prior to 1988. Interannual SST at Jukung contrasts with the inshore Bidadari record between 1996 to 2005.

4.4 Coral Sr/Ca, ENSO and South Eastern Indian Ocean (SEIO) SST

To investigate the link between the Seribu island proxy and instrumental records to remote climate forcing on interannual time scales, coral Sr/Ca is correlated with both El Niño Southern Oscillation index (ENSO) (Niño 3.4 index; Kaplan et al. 1998) and South Eastern Indian Ocean (SEIO) SST. All correlations were made for the three months running averages. SEIO SST from ERSST (data at: http://climexp.knmi.nl/) is used to include potential transport of water masses from the Indian Ocean observed in response to the seasonally changing monsoon circulation (Qu et al., 2005). Furthermore, SEIO SST perturbations are often associated with Indian Ocean Dipole (IOD; September to November) and/or ENSO events and by regional, monsoonal air-sea interactions independent of IOD/ENSO (Terray et al., 2007). It is therefore important to test for the influence of both ENSO and the SEIO on Seribu Island waters.

The relationship for three months averages between coral Sr/Ca-SST for Jukung and Bidadari for period of 1968-2005 and 1973-2005, respectively, with ENSO/SEIO SST is similar to that obtained for period 1992-2005 used for proxy calibration. This indicates that increasing the length of the time series had little impact on the above results (see the supplement data 1).

During DJF (December January February) and MAM (March April May), high positive correlations were observed between Seribu Islands ERSST and Niño3.4. This means that when the SST anomaly (SSTa) is high in the Nino3.4 (ENSO) region, the Seribu Islands SST anomalies (SSTa) are also high in DJF and MAM. The correlation becomes negative in JJA (June July August) and SON (September October November) (Figure 4). This means that when the SSTa in the Nino 3.4 region is high (El Nino event), the SST in the Seribu Islands is low in JJA and SON. Positive correlations were observed between AirT and Niño3.4 during SON and DJF, but not during MAM and JJA.

The Jukung Sr/Ca record revealed a negative correlation with Niño3.4 in DJF and MAM, indicating warmer SST during El Niño events. This agrees with the relationship observed in instrumental SST, yet the relationship is weaker than in ERSST, albeit statistically significant. Bidadari Sr/Ca revealed a negative correlation with Niño3.4 during SON and DJF, in line with the established relationship between AirT and Niño3.4.

The offshore (Jukung) and inshore (Bidadari) coral Sr/Ca records revealed contrasting results with respect to ENSO (Figure 4). The correlation of the Jukung Sr/Ca with the Niño 3.4 index shows that SST in the offshore Seribu region was cooler than normal during the onset phase of an El Niño event (SON), while Bidadari Sr/Ca recorded warmer inshore temperatures during SON. The inshore Bidadari coral responded similarly to an El Niño event as Jakarta (ciledug) AirT.

The correlation between Seribu Island ERSST and the SEIO SST is positive during all seasons. The correlation between the offshore Jukung Sr/Ca record and the SEIO SST is negative for all seasons, as expected from the inverse relationship between coral Sr/Ca and SST. This indicates that cooling/warming of SST in the SEIO co-varies with the sign of SST in the Jukung region. The correlation between Bidadari Sr/Ca and SEIO SST was negative in most seasons, but became positive during SON. Thus, during SON, cool SST in the southeastern Indian Ocean coincided with high SST in Bidadari Sr/CaSST (Figure 4). This agrees with the relationship observed between AirT and SEIO SST, thus indicating that the inshore and offshore corals show different relationships with SEIO SST variability during SON. Confounding influences of regional SEIO air-sea interactions associated with background monsoonal climate variations might have caused differing responses in SON during ENSO/IOD events for our inshore and offshore coral reefs. The latter might be related to water mass transport anomalies (horizontal and vertical advection) between the Java Sea and the SEIO (Qu et al., 2005; Terray et al., 2007; Halkides et al., 2011). However, the relationship with both ENSO and SEIO SST are in general weaker and shows a larger spread for the coral time series than with observational ERSST and AirT. Yet, the correlation sign tendency is always correct. The weaker correlations are probably due to slight age model or reconstruction uncertainties in our coral proxy time series. The relationships observed in this study are comparable to other coral paleoclimatological studies from the region (Cahyarini et al., 2009, 2014; Abram et al., 2007, 2008; Charles et al., 2003).

4.5 AirT relationship of inshore Seribu Island corals

Several lines of evidence presented above indicate that the Bidadari coral provides us with a record of inshore SST that is particularly sensitive to AirT. The most likely explanation for the apparent link to AirT is that SST in the shallow waters off Jakarta are strongly influenced by atmospheric circulations (wind-evaporation feedback) anomalies and resulting air-sea interactions, i.e. net heat flux variations. SST variability in the Java Sea is understood to be controlled by bathymetry, net heat flux and the monsoon (Qu et al., 2005). Net heat flux exerts the strongest control on Java Sea SST and also influences AirT (Sachoemar & Yanagi, 2000; Halkides et al., 2011). This net heat flux is strongly related to the land-sea breeze. The land-sea breeze in Jakarta is thought to extend its influence over more than ~50 km (Hadi et al, 2002). The collected coral sample from Bidadari (~30 km from Jakarta) was obtained from shallow depth, where the ambient atmosphere considerably influences the SST. Thus, we suggest that the location of Bidadari close to Jakarta Bay makes it more susceptible for ocean-atmosphere interaction (heat fluxes) associated with land-sea breezes that impact SST.

5. Conclusions

This study has shown that the offshore coral is a good proxy of SST while the inshore coral, in contrast, is a better proxy of air temperature (AirT) variability surrounding Jakarta. This indicates that the urbanization and the concomitant air temperature anomalies are a dominant source of temperature anomalies in the inshore coral reefs of the Seribu waters through regional air-sea interactions. Inshore corals from Bidadari and proximate islands thus may provide useful proxy archives to monitor temperature prior to weather station recordings and might be suitable archives to study the influence of urbanization on the nearby Seribu Island reefs complex.

The results of this study indicate that the Seribu islands reef complex temporally responds differently to the Pacific and Indian Ocean climate variability. During the El Niño onset phase, the inshore coral showed warming while the offshore coral indicated cooling. In the mature phase of El Niño (DJF), both inshore and offshore corals showed warm temperature anomalies. The SEIO SST is the most closely related to temporal SST anomalies across the Seribu islands reef complex throughout the seasons. The results of this study clearly indicate that proxy record locations in Indonesia need to be chosen carefully in context with meteorological evidence in order to identify the seasonal climate response to local and remote climate and anthropogenic forcing.

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References

Abram, N.J., M.K. Gagan, Z. Liu, W.S. Hantoro5, M.T. McCulloch and B.W. Suwargadi (2007). Seasonal characteristics of the Indian Ocean Dipole during the Holocene epoch. Nature, doi:10.1038/nature05477.

Abram, J.A., M.K. Gagan, J.E. Cole, W.S. Hantoro, and M.Mudelsee (2008). Recent intensification of tropical climate variability in the Indian Ocean. Nature, doi:10.1038/ngeo357.

Aldrian, E., and R.D. Susanto (2003). Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature. International Journal Climatology, 23, p.1435-1452.

Aldrian, E., and Y.S. Djamil (2008). Spatio-temporal climatic change of rainfall in East Java Indonesia. International Journal Climatology, 28, p.435-448.

Brown, B.E., and Suharsono (1990). Damage and recovery of coral reefs affected by El Niño related seawater warming in the Thousand Islands, Indonesia. Coral Reef, doi: 10.1007/BF00265007.

Cahyarini, S.Y., M. Pfeiffer, I.S. Nurhati, E.Aldrian,W.-C.Dullo and S. Hetzinger (2014). Twentieth century sea surface temperature and salinity variation at Timor inferred from paired coral $\delta^{18}O$ and Sr/Ca measurements. Journal of Geophysical Research: Ocean, 119, p.4593-4604, doi:10.1002/2013JC009594

Cahyarini, S.Y., M.Pfeiffer, and W.Chr. Dullo (2009). Calibration of the Multicores Sr/Ca records-Sea Surface Temperature: Records from Tahiti Corals (French Polynesia). International Journal of Earth Sciences, doi: 10.1007/s00531-008-0323-2

Cahyarini S.Y. and J. Zinke (2010). Geochemical tracer in coral as a sea surface temperature proxy: records from Jukung coral. ITB Journal, Vol. 42B No. 1, p.65-72 ISSN: 1978-3051

Cahyarini S.Y., and J. Zinke (2009). Coastal City Air Temperature Variation Derived from Coral Sr/Ca Ratios: case study Jakarta, Indonesia. Proceedings International Workshop on Integrated Coastal Zone Management, Izmir-Turkey 20-22 October 2009, ISBN 978-975-7895-08

Charles C.D., K. Cobb, M. D. Moore, and R. G. Fairbanks (2003). Monsoon-tropical ocean interaction in a network of coral records spanning the 20th century. Marine Geology, 201, 207-222.

Cleary, D.F.R., Suharsono, B.W. Hoeksema (2006). Coral diversity across a disturbance gradient in the Pulau Seribu complex off Jakarta, Indonesia. Biodiversity and Conservation, 15, p. 3653-3674.

Cleary, D.F.R., L DeVantier, V.L. Giyanto, P. Manto, N.J. de Voogd, P.G. Rachello-Dolmen, Y. Tuti, A. Budiyanto, J. Wolstenholme, B.W. Hoeksema, Suharsono (2008). Relating variation in species composition to environmental variables: a multi-taxon study in an Indonesian coral reef complex. Aquatic Sciences, 70, p.419-431.

Corrége, T. (2006). Sea surface temperature and salinity reconstructions from coral geochemical tracers. Palaeogeography, Palaeoclimatology, Palaeoecology, 232, p. 408-428.

de Voogd, N.J., and D.F.R Cleary (2008). An analysis of sponge diversity and distribution at three taxonomic levels in the Thousand Islands/Jakarta Bay reef complex, West-Java, Indonesia. Marine Ecology, 29, p. 205–215.

Gordon, A.L., D.R. Susanto, and K. Vranes (2004). Cool Indonesian Throughflow as a consequence of restricted surface layer flow. Nature, 425, p. 824 - 828.

Haylock, M., J.L. McBride (2001). Spatial coherence and predictability of Indonesian wet season rainfall. Journal of Climate, 14, p. 3882-3887.

Heiss, G.A., and W.Chr. Dullo (1997). Stable isotope record from recent and fossil *Porites* sp. in the northern Read Sea. Coral Research Bulletin, 5, p. 161-169.

Hetzinger, S., M Pfeiffer, W.Chr. Dullo, E. Ruprecht, D. Garbe-Schönberg (2006). Sr/Ca and δ^{18}O in a fast-growing *Diploria strigosa* coral: Evaluation of a new climate archive for the tropical. Atlantic. Geochemystry, Geophysics, Geosystems, doi:10.1029/2006GC001347.

Inoue, M., A. Hata, A. Suzuki, M. Nohara, N. Shikazono, W.W.S. Yim, W.S. Hantoro, S. Donghuai, and H. Kawahata (2006). Distribution and temporal changes of lead in the surface water in the western Pacific and adjacent seas derived from coral skeleton. Environmental pollution, 144, p. 1045-1052

Kaplan, A., M. Cane, Y. Kushnir, A. Clement, M. Blumenthal, and B. Rajagopalan (1998). Analysis of global sea surface temperature 1856-1991. Journal of Geophysical Research, 103, p. 18 567-18 589.

Linsley, B.K., G.M. Wellington, and D.F. Schrag (2000). Decadal sea surface temperature variability in the subtropical south Pacific from 1726 to 1997 AD. Science 290, p. 1145-1148.

Oldenborgh, G.J., and G. Burgers (2005). Searching for decadal variatios in ENSO precipitation teleconnections. Geophysical Research Letters, doi:10.1029/ 2005GL023110.

Ourbak, T., T. Corrège, B. Malaize, F. Le Cornec, K. Chalier, J. Peypouquet (2006). A high-resolution investigation of temperature, salinity and upwelling activity proxies in corals. Geochemystry, Geophysics, Geosystems, doi: 03010.01029/02005GC001064.

Rachello-Dolmen, P.G., and D.F.R. Cleary (2007). Relating coral species traits to environmental conditions in the Jakarta Bay/Pulau Seribu reef system, Indonesia. Eastuarine, Coastal and Shelf Science, 73, p.816-826.

Salm, R.V., M. Halim, and A. Abdullah (1982). Proposed Pulau Seribu Marine National Park: conservation and tourism. Parks 7, p. 15-20.

Scoffin, T.P., A.W. Tudhope, and B.E. Brown (1989). Fluorescent and skeletal density banding in Porites lutea from Papua New Guinea and Indonesia. Coral Reefs 7, p.169-178

Suharsono, 1998. Condition of coral reef resource in Indonesia. Jurnal Pesisir dan Lautan, 1, p. 44-52

Smith, T.M., R.W. Reynolds, T.C. Peterson, and J. Lawrimore (2008). Improvements to NOAA's Historical Merged Land-Ocean Surface Temperature Analysis (1880-2006). Journal of Climate, 21,p. 2283-2298

Terray P., F. Chauvin, and H. Douville (2007). Impact of southeast Indian Ocean sea surface temperature anomalies on monsoon-ENSO-dipole variability in a coupled ocean–atmosphere model. Climate Dynamic, 28, p.553–580, DOI 10.1007/s00382-006-0192-y

Umbgrove, J.H.F., and J. Verwey (1929). The coral reefs in the Bay of Batavia. Fourth Pacific Science Congress Java, Excursion, A2, 1–30.

Van der Meij, S.E.T., R.G. Moolenbeek, and B.W. Hoeksema (2009). Decline of the Jakarta Bay molluscan fauna linked to human impact. Marine Pollution Bulletin, 59, p. 101-107.

Van der Meij, S.E.T., Suharsono, B.W. Hoeksema (2010). Long-term changes in coral assemblages under natural and anthropogenic stress in Jakarta Bay (1920–2005). Marine Pollution Bulletin, 60, p. 1442-1454.

Zinke, J., W.Chr. Dullo, G.A. Heiss, A. Eisenhauer (2004). ENSO and Indian Ocean subtropical dipole variability is recorded in a coral record off southwest Madagascar for the period 1659 to 1995. Earth and Planetary Science Letters, 288, p. 177-194.