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Seasonal variation of $\delta^{13}C$ content in *Porites* coral from Simeulue Island waters for the period of 1993-2007

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Abstract - Variation of $\delta^{13}C$ content in coral skeletons shows the influence of metabolic fractionation in aragonite coral. Understanding coral $\delta^{13}C$ variation can thus be useful to more understand *e.g.* past bleaching event which is further useful for coral health and conservation. In this study, $\delta^{13}C$ content in *Porites* coral from Labuhan Bajau, Simeulue Islands was analyzed. To know the correlation between variation of coral $\delta^{13}C$ and light intensity, the monthly variation of coral $\delta^{13}C$ is compared to solar radiation and cloud cover. The result shows that for the period of 2003 to 2008, coral $\delta^{13}C$ shows it is well correlated (r=0.42 p=0.153) with cloud cover variation in annual mean scale. Meanwhile, in seasonal mean variation, coral $\delta^{13}C$ is strongly influenced (r=0.85 p<0.0001) by cloud cover with 1 - 2 month time lag. Comparing to the solar radiation (cloud cover), SST influences dominantly the variation of coral $\delta^{13}C$ from southern Simeulue Island waters (LB sample) in an annual mean scale than in a seasonal scale.

Keywords: $\delta^{13}C$, coral, *Porites*, solar radiation, cloud cover, SST

Introduction

A study of stable carbon isotopic composition ($\delta^{13}C$) content in coral skeletons shows that $\delta^{13}C$ composition is primarily influenced by metabolic fractionation (*e.g.* McConnaughey, 1989; Grottoli, 2002) *i.e.* influenced by photosynthesis and respiration (McConnaughey,1989; Grottoli, 2002, *in* Rodrigues and Grottoli, 2006). Decreased coral $\delta^{13}C$ coinciding with bleached coral (Porter *et al.*,1989, *in* Rodrigues and Grottoli, 2006) is due to decreased photosynthesis, while increased zooplankton decreased $\delta^{13}C$ is via respiration (Felis *et al.*,1998; Grottoli and Wellington, 1999, *in* Rodrigues and Grottoli, 2006).

Understanding $\delta^{13}C$ content in coral skeleton is useful to more understand a physiological factor which is a base to more understand the bleaching event and further to the coral health and conservation (Rodrigues and Grottoli, 2006). In this study, $\delta^{13}C$ content in *Porites* coral from Labuhan Bajo Simeulue waters was analyzed. Monthly variation of coral $\delta^{13}C$ is compared to the solar radiation and cloud cover to understand the influence of light intensity to the coral $\delta^{13}C$. This study can be as a base for a historical coral development study for a longer time window, *i.e.* hundreds to thousands year ago. Further, the study is able to support the coral reef conservation activities in the Simeulue ocean waters.

Materials and Methods

Porites coral core was collected in July 2007 from 25 m depth of Labuhan Bajo Village, east-southern coast of Simeulue Island (sample code LB) (~ 02.23° N 096.29° E). The coral core was slabed into 0.5 cm thick and the coral slabs were X-rayed with 3 Kvp to picture clear density band. Water pressure cleaning was done to the coral slabs to remove dust, then ultrasonic bath cleaning followed. X-rayed coral slabs were then used to perform the coral banding (Figure 1). Subsampling using hand drilling (1 mm bit) was done along the coral growth axis to get the coral powder samples. Coral powder samples were then analyzed for $\delta^{13}C$ using Gasbench Delta Plus at the Free University Amsterdam. The powdered samples were reacted with H_3PO_4, and the resulting CO_2 gas was analyzed in the mass spectrometer. All samples are reported in ‰.

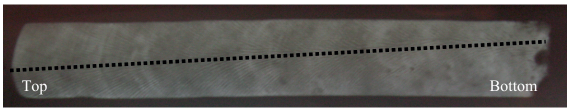

Figure 1. X -Rayed of *Porites* coral slab sample LB. Dashed lines are subsampling transect along the growth axis.

Coral XDS software was used to calculate the paired high/low density which was used to developed preliminary chronology in annual scale. One year growth is represented by a dark and light coral band in x -rayed coral. The detailed chronology (*i.e.* monthly scale) of $\delta^{13}C$ is based on coral Sr/Ca chronology development (see Cahyarini, 2011). Paired density band calculation result in that LB *Porites* coral is about ~14 years old. The chronology development of coral $\delta^{13}C$ results in period ranges from July 1993 to August 2007. Monthly variation of $\delta^{13}C$ from *Porites* coral (sample code LB) for the period of 1993-2007 is shown in Figure 2.

Historical data used in this study involved solar radiation, cloud cover, and coral SST. Solar radiation data are obtained from Fresco v.6 averaged over 2x2 grid boxes resolution (from Wang *et al*., 2008) and available from 2002- 2007. Cloud cover data are obtained from ICOADS with 2x 2 grid resolution and available from 1996-2007. Variable cldc (Cloudiness Monthly Mean at Surface) is in okta. *ICOADS data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/.*

SST derived from coral Sr/Ca (further mentioned as coral SST) was used in this study to indicate the influence of SST to the variation of coral $\delta^{13}C$. Coral SST is obtained from Cahyarini, (2011).

Results and Discussions

The analysis of $\delta^{13}C$ content in coral skeleton sample LB using Gasbench Delta Plus in monthly resolution is shown in Figure 2. Monthly variation of coral $\delta^{13}C$ (Figure 2) ranges from -3.39±0.42‰ to -2.07±0.42‰ with the mean value -2.98±0.42‰ for the period of 1993-2007. For the period of 2003 to 2008, decreasing trend of solar radiation supposes decreasing trend of coral $\delta^{13}C$ from this region (Figure 3), which confirms the published work *i.e.* for the healthy coral as solar radiation decrease, decreased coral $\delta^{13}C$ is due to decreasing

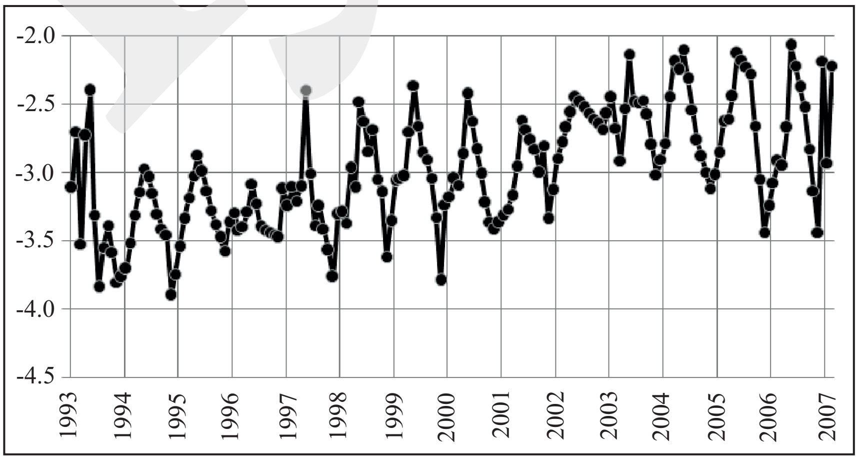

Figure 2. Monthly variation of $\delta^{13}C$ content in *Porites* coral (sample code LB) from Labuhan Bajo.

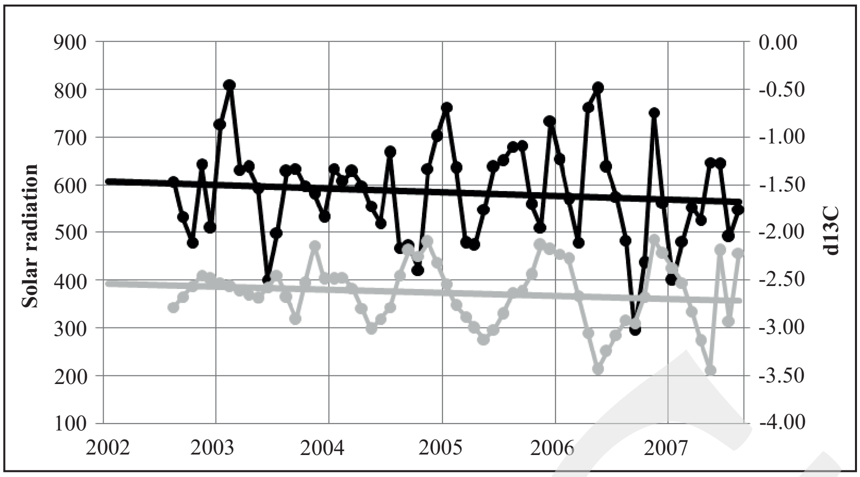

Figure 3. Graphic of monthly variation of coral $\delta^{13}C$ (grey line) and solar radiation (dark line) and its trend lines (bold grey and dark lines).

photosynthesis (Grottoli, 2002; Heikoop *et al*., 2002). In some year periods, the seasonal cycles of $\delta^{13}C$ shows out of phase compared to solar radiation seasonal cycles, *i.e.* from 2005 to 2007, when the high solar radiation coincides with low $\delta^{13}C$. This suggests that this period coincided with the weak ENSO event when the seawater temperature anomaly slowed down the enrichment of $\delta^{13}C$ in the coral skeletons. During the normal condition, coral $\delta^{13}C$ enrichment normally follows the solar radiation cycle.

Seasonal mean variation of solar radiation varies out of phase with the cloud cover, *i.e.* high solar radiation coincides with low cloud cover (Figure 4). In the studied areas, the maximum solar radiation is in February (641.25 w/m^2) and the minimum is in August (495.09 w.m^2), while cloud cover maximum is in October (0.45) and minimum is in Februari (0.27). Seasonal mean variation of solar radiation and $\delta^{13}C$ coral shows a good correlation in 1 month time lag. The maximum $\delta^{13}C$ is in November and the minimum is in May. Figure 4 shows monthly mean variation of solar radiation, cloud cover, and $\delta^{13}C$ coral. Solar radiation supposes some time to reach the coral in 25 depths to influence its $\delta^{13}C$ variation.

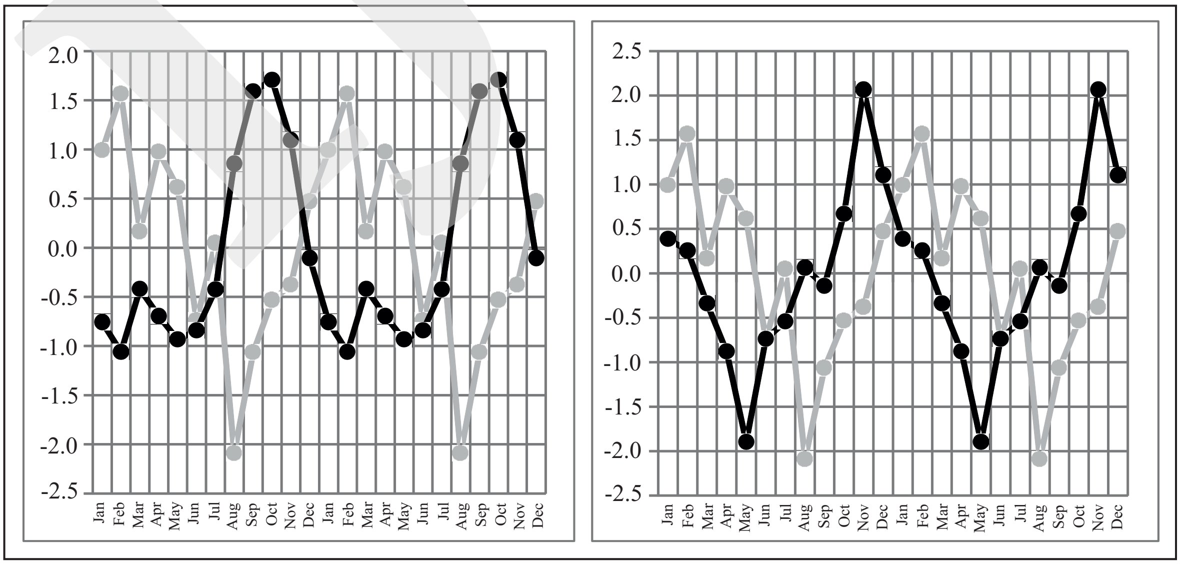

Figure 4. Graphic of monthly mean variation of solar radiation (grey line) and (left) cloud cover (dark line) and (right) $\delta^{13}C$ (dark line). The data are corrected for two month lag. All time series data are standardized.

Decreasing photosynthesis due to decreasing light condition may be caused by increasing cloud cover, which causes decreasing $\delta^{13}C$ in coral skeletons. Decreasing $\delta^{13}C$ content in Simeulue coral is supposed to relate to decreasing light in the depth of *Porites* coral (LB). This is convinced that the maximum $\delta^{13}C$ amount in coral skeletons occurred during a maximum light.

An annual mean $\delta^{13}C$ of LB coral sample and cloud cover are compared (Figure 5). The result shows that during ~10 years, from period of 1996 to 2007, decreasing trend of $\delta^{13}C$ coral follows increasing trend of cloud cover. Correlation between these two series convinces that annual mean $\delta^{13}C$ of LB coral is correlated with cloud cover (r=0.424 p=0.169) (Figure 6). The variation of coral $\delta^{13}C$ relative to cloud cover variation is about 0.123‰/okta *(0 clear cloud to 8 overcast)*. It suggests that the clearer the cloud, the more $\delta^{13}C$ content in coral.

Sr/Ca content in LB coral shows a local sea surface temperature (SST) at a coral site (Cahyarini, 2011). Reconstructed SST based on Sr/Ca content in LB coral (further mentioned as coral SST) (Cahyarini, 2011) was used to understand the influence of SST to the variation of coral $\delta^{13}C$. Coral SST was compared and correlated with coral $\delta^{13}C$ (Figure 7). The result shows that

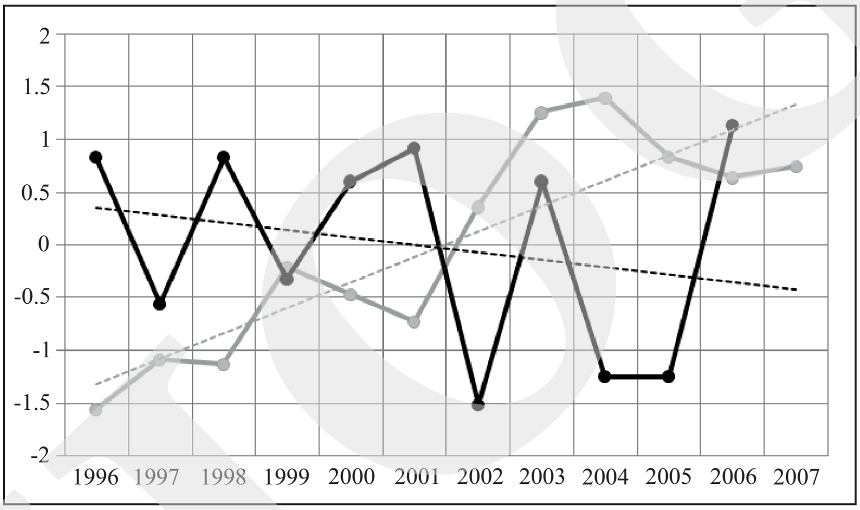

Figure 5. Annual mean variation of $\delta^{13}C$ (grey line) and cloud cover (dark line). Linear trend line (dashed line). Data are standardized to unit variance.

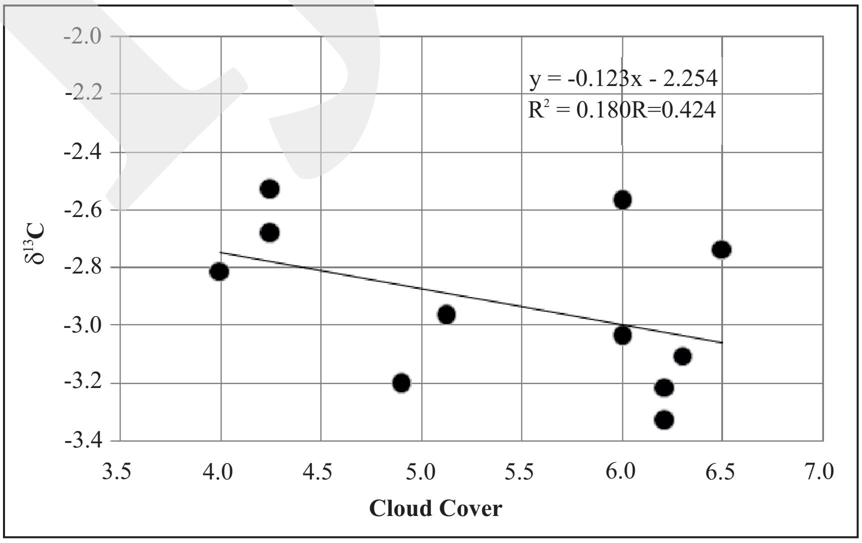

Figure 6. Linear regression of cloud cover and $\delta^{13}C$ in the annual mean scale.

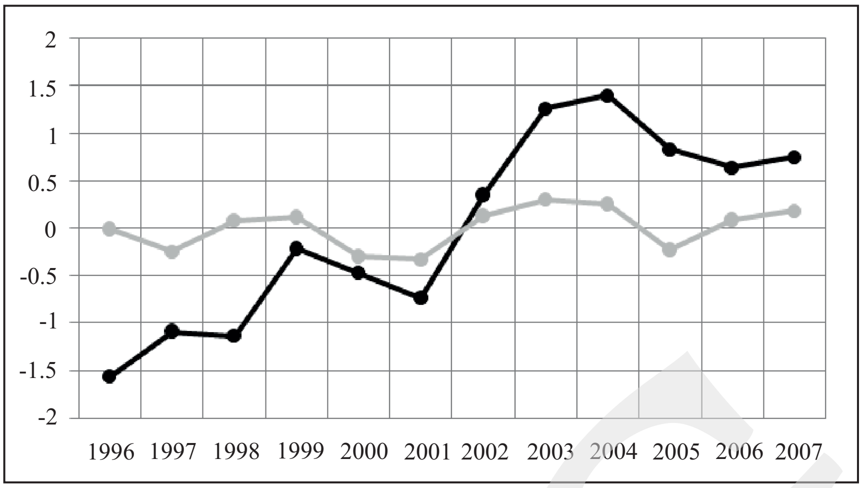

Figure 7. Annual mean variation of coral $\delta^{13}C$ (dark line) and SST (grey line) derived from coral Sr/Ca. Data are standardized to unit variance.

in annual mean resolution, correlation between coral SST and $\delta^{13}C$ is high (r=0.54 p=0.057). It suggests that the influence of SST to the variation of $\delta^{13}C$ is higher than that with cloud cover (solar radiation) in annual mean scale. In seasonal variation, coral $\delta^{13}C$ change respond to SST is low (r=0.387 p<0.0001). It supposes the SST variation is dominant in changing the $\delta^{13}C$ content in LB coral in the annual mean scale rather than in seasonal scale.

Conclusions

The $\delta^{13}C$ variation content in coral from Labuhan Bajo (LB) east –southern Simeulue Island is well correlated with cloud cover variation in annual mean scale. In seasonal scale, variation of $\delta^{13}C$ content in LB coral is influenced by cloud cover with 1-2 month time lag. Variation of coral $\delta^{13}C$ is dominantly influenced by SST in annual mean than in seasonal variation.

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