FIELD CORRELATION BETWEEN PRECIPITATION-EL NINO RELATED VARIATION AND CORAL δ^{18}O

By :

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ABSTRACT

Coral δ^{18}O from Maudulung-Indonesia was analyzed using Finnigan MAT 251. Using statistical analysis from KNMI database is obtained that the seasonal mean field correlation between coral δ^{18}O-SOI shows strong correlation during October. Field correlation of precipitation-coral δ^{18}O shows opposite pattern between eastern Pacific and western Pacific during strong El Nino event.

Keywords: coral δ^{18}O, field correlation, El Niño, Maudulung Sumba.

SARI

Kandungan δ^{18}O dalam koral dari wilayah Maudulung, Sumba, dianalisis dengan menggunakan Finnigan MAT 251. Korelasi spasial antara δ^{18}O dengan SOI dalam skala musiman tinggi selama bulan Oktober. Korelasi spasial ini dilakukan dengan menggunakan fasilitas analisa statistik dalam database KNMI. Korelasi spasial antara presipitasi- coral δ^{18}O menunjukkan pola-pola yang berlawanan antara wilayah timur dan barat Pasifi selama El Niño.

Kata kunci: Koral δ^{18}O, korelasi spasial, El Niño, Maudulung Sumba.

INTRODUCTION

According to the standard paleotemperature relationship for carbonates, when the oxygen isotopic composition of seawater is constant, coral skeletal δ^{18}O records the changes of SST for 0.22 ‰/°C (Weber and Woodhead, 1972). When the seawater δ^{18}O varies in response to change in precipitation, evaporation and water advection, δ^{18}O in coral will mirror the seawater δ^{18}O variations (Cole, et.al., 1993, Gagan et al., 1994, Linsley et al, 1994). Precipitation is one of the important parameters to study climate phenomena such as El Nino events. Several researchers have used coral δ^{18}O to develop precipitation reconstruction from sites where seawater δ^{18}O correlates with rainfall (Cole et al.,1993; Linsley et al., 1994).

During El Nino events, when the centre of ocean (western Pacific warm pool or WPWP) heating and accompanying convective

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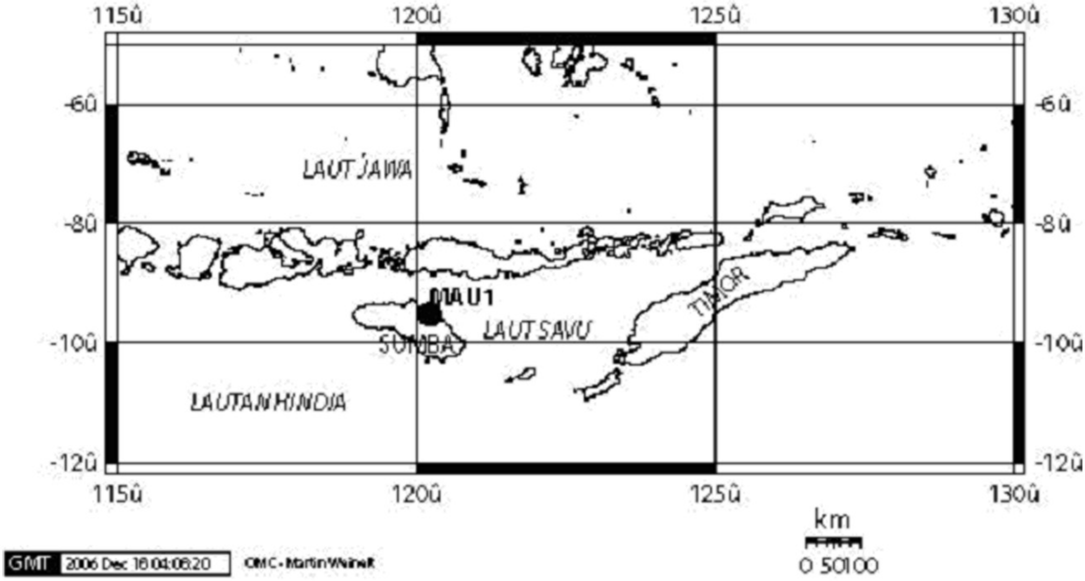

Figure 1. Site location

precipitation moves eastward producing severe drought in Indonesia and bringing high rainfall anomaly to the central Pacific. The El Nino induced drought in the WPWP region (e.g Indonesia) because of the reduction of precipitation (the weakening of tradewind velocities reduces rainfall). We suppose that coral $\delta^{18}O$ record rainfall related to the El Nino event. We analyze coral $\delta^{18}O$ from Maudulung, Sumba- Indonesia (120.5°W, 9.8°S). In this study we discuss the spatial pattern of coral $\delta^{18}O$ and precipitation relationship and its variation during the strong El Nino events.

CLIMATOLOGY OF THE STUDY AREA

Based on climatology data of Maudulung waters (120.5 E, 9.8 S), the maximum sea surface temperature (SST) occurs during March and the minimum

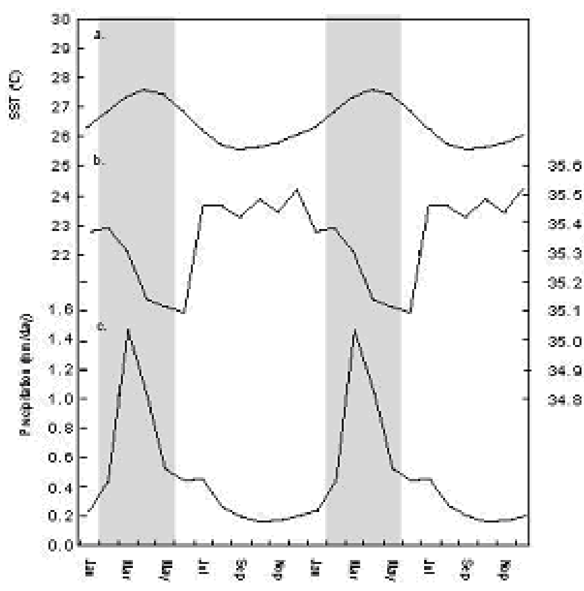

Figure 2. Monthly mean of SST (Reynold & Smith, 1994) (a), SSS (Levitus, 1994) (b) and Precipitation (c). Shadow box is warm and wet months (February-May)

SST, during September (Figure 2), while maximum precipitation is on March and the minimum precipitation is on November.

In this study area, higher sea surface salinity (SSS) start from July to March the following years, and maximum during December. The lower SSS start from April to June which minimum occurs during June (Figure 2). SST varies from 25.6° to 27.6°C. Precipitation varies from 0.2 to 1.5 mm/day, while SSS varies from 35.1 to 35.2 psu.

MATERIAL AND METHODS

Modern colonie of *Porites sp* from Maudulung, Northern Sumba, Indonesia (120.5 E, 9.8 S) was drilled on November 1998. The 70 cm core long with diameter of 7 cm is used for coral $\delta^{18}O$ analysis. The core is sliced perpendicular to coral growth axis to get 7 mm thick slab. The core slab is used for detail sampling using the milling following the method of Gagan et al. (1994). $\delta^{18}O$ in coral is analyzed using Finnigan MAT 252 mass spectrometer at RSES, ANU. The chronology is developed based on peak matching between $\delta^{18}O$ and the instrumental SST dataset from NCEP using Analyseries software (Paillard et.al.,1996). The coral $\delta^{18}O$ extends from July 1988 to November 1998. Detail of the material and methods describe in Cahyarini et al. (2003). We use also statistical analysis method available in Royal Netherlands Meteorological Institute (KNMI) database (http:// www.knmi.nl/).

RESULT AND DISCUSSIONS

Oxygen isotope ($\delta^{18}O$) in coral composition is believed as a function of both $\delta^{18}O$ seawater and temperature (Charles, et al., 1997; Quinn, et al., 1998; Gagan, et al., 2000). The mean $\delta^{18}O$ of coral aragonite is offset from seawater, most likely due to biological processes (McConnaughey, 1989). Assuming that this disequilibrium is constant in time, the relationship between coral $\delta^{18}O$, SST and seawater $\delta^{18}O$ will be linear. In the seasonal scale the linear regression of Maudulung coral $\delta^{18}O$ -SST result in calibration slope of -0.06 ‰/°C (Cahyarini et al., 2003), which is lower than the slope of carbonate $\delta^{18}O$ -SST relationship. It is suggested that coral $\delta^{18}O$ Maudulung core is not only influenced by SST but also seawater $\delta^{18}O$.

Oxygen isotope of seawater variations ($\delta^{18}O_{sw}$) are related to the hydrological balance (precipitation-evaporation) and salinity, which both are important climatic parameters. As coral $\delta^{18}O$ recorded from Maudulung influenced both SST and $\delta^{18}O_{sw}$ (e.g. Cahyarini et al., 2003), we do field correlation of coral $\delta^{18}O$- precipitation using statistical data processing from *Koninklijk Nederlands Meteorologisch Institut* (KNMI) (Oldenborgh & Burgers, 2005). To verify field correlation of coral $\delta^{18}O$ - precipitation, we do field correlation between instrumental precipitation dataset from NASA GPCP V1B satellite gauge precipitation. The data is available at (http:// ingrid. ldgo. columbia. edu/. source/. NASA/) for grid point of Maudulung (120.5°W, 9.8°S) and precipitation field dataset. The field correlation between coral $\delta^{18}O$ and precipitation in grid point of Maudulung shows the similar pattern with field correlation between precipitation dataset (Figure 3).

El Nino is the most prominent climate phenomena which characterized by the higher SST anomaly (SSTa) in the eastern Pacific and lower SSTa in the western Pacific than the normal SST. During El Nino usually the SST in the part of Indonesian region is lower than normal e.g. western Sumatra and southern Java. In these locations there are upwelling. Drought cover most part of Indonesian land because of less precipitation in this region. This is shown by the clear pattern of the opposite precipitation pattern in the western and eastern Pacific (Figure 3). During El Nino, rainfall and thunderstorm activity diminishes over the western equatorial Pacific, and increases over the eastern half of the tropical Pacific. According to the Climate Prediction Centre (CPC) National Oceanic and Atmospheric Administration (NOAA), this area of increased rainfall occurs where the exceptionally warm ocean waters have reached about 28°C or 82°F. This overall pattern of rainfall departures spans nearly one-half the distance around the globe, and is responsible for many of the global weather impacts caused by El Niño.

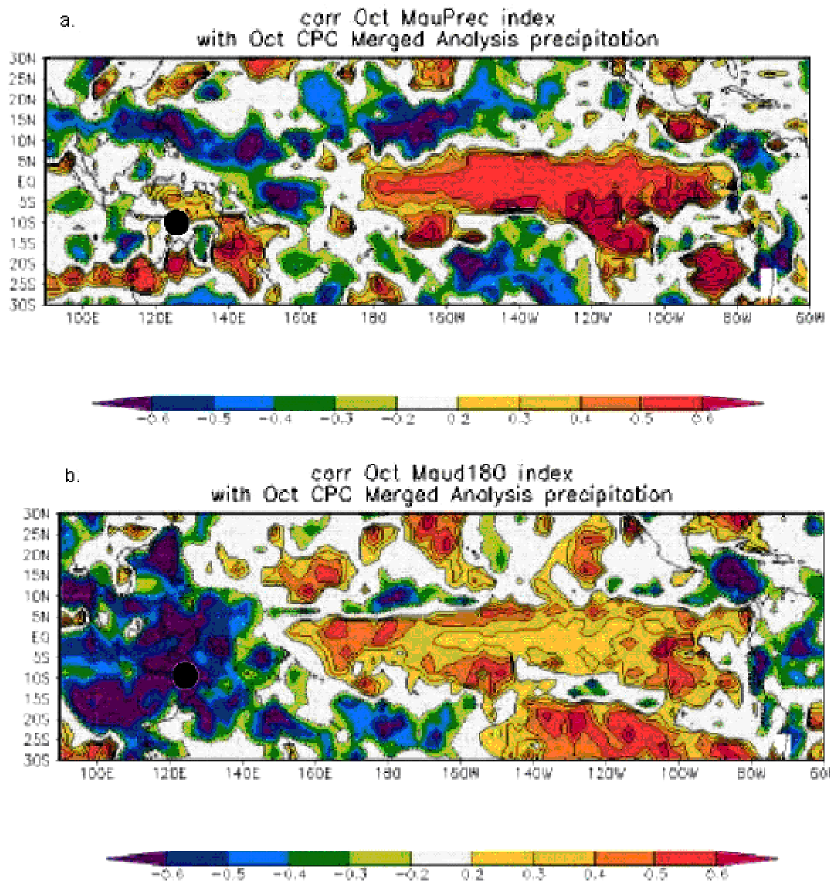

Figure 3. (a) Field correlation between precipitation dataset and (b) field correlation of coral 18O from Maudulung and precipitation.

Coral $\delta^{18}O$ is influenced by SST and seawater $\delta^{18}O$. Further, seawater $\delta^{18}O$ variation is interpreted as precipitation contribution in the coral. Also, to know whether the El Nino variation recorded in coral $\delta^{18}O$ Maudulung or not, we correlate the seasonal mean coral $\delta^{18}O$ with Southern Oscillation Index (SOI). SOI is one measure of the large-scale fluctuations in air pressure occurring between the western and eastern tropical Pacific (i.e., the state of the Southern Oscillation) during El Niño and La Niña episodes. Traditionally, this index has been calculated based on the differences in air pressure anomaly between Tahiti and Darwin, Australia. In general, smoothed time series of the SOI correspond very well with changes in ocean temperatures across the eastern tropical Pacific. The negative phase of the SOI represents below-normal air pressure at Tahiti and above-normal air pressure at Darwin.

Prolonged periods of negative SOI values coincide with abnormally warm ocean waters across the eastern tropical Pacific typical of El Niño episodes.

We correlate each month in a given year with the SOI and high correlation coefficient between coral $\delta^{18}O$ vs. SOI is R= 0.5-0.6 found during the boreal winter (November-February) which is usually strong El Nino happened. However, highest correlation (r= 0.7) between coral $\delta^{18}O$ Maudulung and SOI is obtained during October mean (Figure 4). We suggest that at the study area (Maudulung) the strong El Nino season is on October recorded by coral $\delta^{18}O$.

To convince that coral $\delta^{18}O$ correlate with El Nino, the coral $\delta^{18}O$ is correlated with Nino 3.4 index. Nino 3.4 index is the SSTa at the Nino 3.4 region (5S-5N; 170W-120W). Nino 3.4 region is the region that has large variability on El Niño time scales, and that is closer (than NINO3) to the region where changes in local sea-surface temperature are important for shifting the large region of rainfall typically located in the far western Pacific.

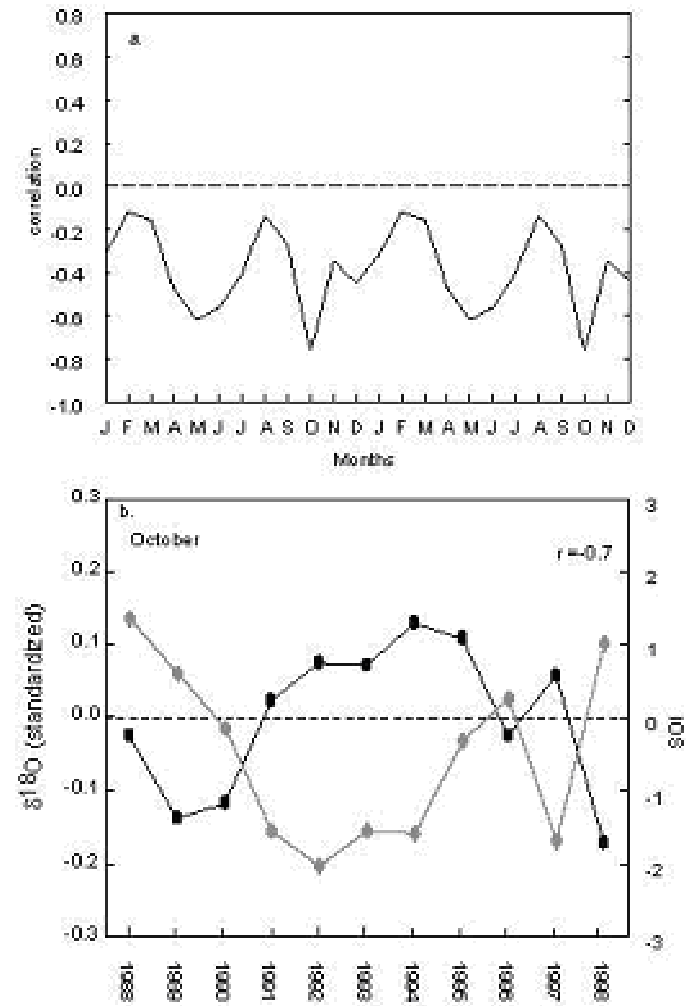

Figure 4. (a.) Correlation of coral 18O Maudulung, Sumba records with Southern Oscilation index (SOI). Timeseries starting all months, average 1 month. Data processing use statistical analysis from KNMI. (b) Variation of coral 18O (dark line) and SOI (grey line) during October.

The correlation between coral $\delta^{18}O$ and Nino 3.4 index is low (R= 0.3-0.4) in the monthly scale. However, the highest correlation is during October mean (R=0.6) by putting 1 month positive lag, i.e., coral $\delta^{18}O$ exceed Nino 3.4 index. In the seasonal mean average, the correlation between coral $\delta^{18}O$ and Nino 3.4 index is also low during boreal winter mean (R=0.4) when the El Nino is strong. However, both seawater $\delta^{18}O$ and SST incorporated in the coral $\delta^{18}O$ also it is not surprising if the correlation between coral

$\delta^{18}O$ and Nino 3.4 index is low (R=0.4), since the Nino 3.4 index is SST only. However, in this region, i.e., Nusatenggara, the precipitation incorporates strongly in the coral $\delta^{18}O$ (e.g., Charles et al., 1997). Since coral $\delta^{18}O$ do not shows SST only, it is needed the proxy which shows SST only i.e Sr/Ca. It is believed that Sr/Ca in coral shows SST only as long as the coral sampling along the growth axis (e.g., Gagan et al., 2000). During boreal winter, the correlation between SST dataset in grid point of Maudulung and Nino 3.4 index is high (R= 0.5-0.6), also it is expected that coral Sr/Ca from Maudulung will also high correlate with Nino 3.4 index during boreal winter. Therefore, it is required to analyze Sr/Ca from the Maudulung coral core.

CONCLUSIONS

Coral $\delta^{18}O$ recorded from Maudulung core is not only influenced by SST but also seawater $\delta^{18}O$. Seasonal mean correlation of coral $\delta^{18}O$ -SOI shows that highest correlation (r= -0.7) is obtained during October. The low correlation is obtained betweed coral $\delta^{18}O$ vs. Nino 3.4 index (R=0.4). The field correlation coral $\delta^{18}O$ - precipitation shows clearly pattern during strong El Nino months (October), the lower precipitation in the western Pacific, the higher precipitation in the eastern Pacific. However, it is required to analyze $\delta^{18}O$ in coral from this study area for longer time scale and to analyze this core using another proxy such as Sr/Ca ratio, which is influenced by SST only. Further SST-El Nino related variation can be assessed. Using paired proxy coral $\delta^{18}O$ and Sr/Ca then can be used to reconstruct Oxygen isotope of seawater variations and furthermore to interpret accurately SST and precipitation in this area.

ACKNOWLEDGEMENT

We thank to RSES-ANU for the sample analysis.

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