Simple Statistical Testing on Existing Data of Core 39 KL SO189/2 to Reveal its Correlation Towards Sea Surface Temperature Variation

Uji Statistik Simpel pada Data Eksisting Sedimen Inti 39 KL SO189/2 untuk Mengungkap Korelasinya terhadap Variasi Suhu Muka Laut

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(Received 2 October 2020; in revised form 5 October 2020; accepted 27 November 2020)

ABSTRACT: Several paleotemperature proxies using marine core sediment data have been developed and well-proven, but they need excellent laboratory handling and destructive tools. Spectrophotometer and Multi-Sensor Core Logger (MSCL) is considered rapid and non-destructive tools compared to other climate proxies. This paper enhances the correlation between existing data of spectrophotometer, MSCL, and sea surface temperature (SST) of the sediment core 39 KL from SO189/2 through a statistical test. The dataset is processed using interpolation, Pearson correlation, and K-means clustering. Pearson correlation reveals a strong correlation between spectrophotometer, MSCL, and SST. K-means clustering points out that SST is shifting from relatively colder to warmer. This study also tries to understand the source of four tephra and one terrigenous layer. It can be concluded that the spectrophotometer and MSCL have a positive correlation to SST variation.

Keywords: statistical approach, existing data of SO189/2, spectrophotometer, Multi-Sensor Core Logger, sea surface temperature

INTRODUCTION

Sea Surface Temperature (SST) is among global climate change indicators and can be reconstructed based on several proxies applied to marine sediment core (Bradley, 2015). Those proxies studied in the mentioned reference are well-proven. However, the methods were destructive and need sample preparation. Rothwell (2006) summarized non-destructive techniques, rapid, and relatively cheap for sediment core analysis, including spectrophotometry (lightness/L* and chlorins/Cl), gamma-ray attenuation (GA), and magnetic susceptibility (MST), which are possible to infer climate changes (Nederbragt et al., 2006; Rogerson et al., 2006; Rothwell and Rack, 2006). Nederbragt et al. (2006), using a quantitative method, presents that L* and total organic carbon (TOC) are negatively correlated. Rogerson et al. (2006) indicate that low L* value is associated with Holocene dry events.
GA and MST are commonly used in core and well log analysis. In terms of paleoclimatology, GA and MST may benefit for a benchmark of orbital force and astrochronology (Huber et al., 2018). Thamban et al. (2005) conclude that repetitive fluctuation in MST could be comparable to the glacial-interglacial cycle. Furthermore, gamma attenuation represents clay content, while magnetic susceptibility may reflect terrigenous influx. Both also deliver a hydrodynamic force and humidity environment, which exhibit a relatively positive correlation (Cao et al., 2012). Hypothetically, GA and MST are positively correlated to global temperature.

Therefore, this study is conducted to reveal the correlation between the existing data of L*, Cl, GA, MST, and SST variation on the core 39 KL SO189/2 using a statistical approach. The core is collected from northern Bengkulu Basin (also known as Sibehut Basin), Sumatra, Indonesia (Figure 1). Because the 39 KL SO189/2 sediment core is relatively long and has been analyzed for various datasets, we expect it to preserve relatively complete paleoclimatic data. Moreover, four tephra and a terrigenous material layer were identified within the sediment core.

METHODS AND MATERIALS

The datasets of core 39 KL are spectrophotometer, MSCL, core description which collected from SO189-2 cruise report (Wiedicke-Hombach et al., 2006), age from Mohtadi et al. (2014b) and SST from Mohtadi et al. (2017). In this study, spectrophotometer data are lightness (L*) and chlorins (Cl), while MSCL data are gamma attenuation (GA) and magnetic susceptibility (MST). Spectrophotometer and MSCL data format are images, then transformed to discrete data using Graph Grabber v2.0.2 by manual picking. The datasets are processed using linear interpolation. This study workflow is described in Figure 2, and the composite dataset graph is presented in Figure 3.

Data were analyzed by Pearson correlation and K-means clustering analysis, using Minitab 18. Pearson correlation measures the strength and direction of the linear relationship between two variables, while Cluster K-means classify observation into a specified number of groups based on their similarity. K-means clustering analysis involves SST and L*, Cl, GA, and MST variables within 2 and 3 clusters. In this study, clustering number was determined based on SST variation (cooler, transition, warmer) and visualized in a 3D scatterplot by depth (z-axis), SST (y-axis), and L*/Cl/GA/MST (x-axis) to observe its variation in vertical sequence.
Figure 3. Composite data of core 39 KL from SO189/2. Lightness, chlorins, gamma attenuation, and magnetic susceptibility are the result of transformation from image to discrete data. SST and age are the interpolated data (modified from Wiedicke-Hombuch et al., 2006 and Mohtadi et al., 2017). Last Glacial Maximum date according to Clark et al. (2009). Layer A, B, C, and E are tephra layer and Layer D is terrigenous mineral layer.
RESULTS

All data were observed from depth interval of 2 cm below seafloor (cmbsf) down to 1434 cm of the core, except for gamma attenuation (GA) started from 8 cmbsf. Two statistical analyses, Pearson correlation and K-means clustering were implemented. Pearson correlation presents a strong correlation (> 0.7) between SST, L*, Cl, and GA, in contrast with MST (Table 1). A 2D scatterplot delivered K-means clustering analysis of SST against depth and a 3D scatterplot of depth (z-axis), SST (y-axis), and L*/Cl/GA/MST (x-axis), featured in Figure 4 and 5. Using K-means clustering to SST, the boundary between clusters can be found. In SST against depth (Figure 4), the boundary between 2 cluster division is ~19.705 (675 cm), while boundaries between 3 clusters are ~27.077 kya (898 cmbsf) and ~12.628 kya (452 cmbsf).

Cluster K-means of SST, L*, Cl, and GA against depth (Figure 5) show similar patterns, either in two or three cluster divisions. Unlike the other variable, MST shows an unclear cluster pattern against SST and depth. The boundaries of 2 clusters in SST against L*, Cl, and GA are at depth 384, 453, and 530 cmbsf, respectively. In the 3 cluster divisions, two boundaries for L*, Cl, and GA are 340 and 433 cmbsf, 418 and 592 cmbsf, and 218 and 570 cmbsf. According to the cluster boundaries, it is discovered L* and GA boundaries are upper than Cl boundaries.

Composite graphic in Figure 3 is displaying all measurement variables. According to the core identification by Wiedicke-Hombach et al. (2006), 4 (four) tephra layers (Layer A, B, C, and E) and 1 (one) layer as terrigenous mineral (Layer D) were observed. Layer A is 0.5 mm thick at depth 1178 cmbsf. Layer B, C, and E are deposited at depth 1087-1090, 438-444, and 63-62.5 cmbsf, respectively. SST slightly increases from 28.662 to 28.764 °C, while other variables are decreased. In contrast to the tephra layers, Layer D has an extremely high MST value, which is 4715.023 at 174 cmbsf and 5849.448 at 173 cmbsf. Layer E describes that SST at 63 to 62 cmbsf increase as well as L*, Cl, and MST, in contrast, GA are increased at that depth interval.

Layer A at 1180 cmbsf upward indicates that all variables (L*, Cl, GA, MST, and SST), have a positive trend. Cl value slightly reduces in a specific spot of this layer (1176-1177 cmbsf), while the other variables increase. In Layer B, SST increase from 26.532 °C at 1090 cmbsf to 26.723 °C at 1087 cmbsf, and GA value indicate a similar trend, in contrast, the pattern of L* and MST is decreased upward. The SST, L*, Cl, and GA of Layer C exhibit a decreasing trend from the bottom part to the upper part. The lowest L*, Cl, and GA values are at 440, 441, and 439 cmbsf, respectively. Afterward, each value increase from its lower peak to 438 cmbsf. SST is relatively constant at 442, 441, and 440 cmbsf in Layer C. Terrigenous layer (Layer D) has a significant increase of SST at 176 cmbsf, that followed by Cl and GA. Furthermore, L* increase gradually from 178 to 175 cmbsf. At 180 to 178 cmbsf, SST slightly increases from 28.662 to 28.764 °C, while other variables are decreased. In contrast to the tephra layers, Layer D has an extremely high MST value, which is 4715.023 at 174 cmbsf and 5849.448 at 173 cmbsf. Layer E describes that SST at 63 to 62 cmbsf decline as well as L*, Cl, and MST, in contrast, GA are increased at that depth interval.

Table 1. Statistic Pearson correlation between SST, L*, Cl, GA, and MST

| Variable | Value |
|----------|-------|
| SST      | L*    |
| Cl       | Cl    |
| GA       | GA    |
| MST      | MST   |

Figure 4. Scatterplot of SST against depth with K-means clustering. Each color represents a cluster. Above is scatterplot with 2 cluster divisions, while below is 3 cluster divisions. The boundary between clusters shown by yellow highlights in depth.
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Figure 5. 3D Scatterplot with K-means clustering of SST to L*, CI, GA, and MST. Left figures are K-means with 2 cluster divisions, while the right models are 3 clusters. Each color represents a cluster.
Figure 6. Composite data of tephra and terrigenous layers of core 39 KL from SO189/2. L*, Cl, GA, and MST are the result of the transformation from image to discrete data. SST is interpolated data (modified from Wiedicke-Hombach et al., 2006 and Mohtadi et al., 2014d, 2017)
DISCUSSIONS

Pearson correlation (Table 1) and scatterplot with K-means clustering (Figure 5) magnify the positive correlation between L*, Cl, GA, and SST variation. 2D and 3D scatterplot with K-means clustering visualize data grouping (Figure 4 and 5). Figure 5 (above) exhibits data which divided into 2 and 3 clusters, which might indicate cooler and warmer conditions. K-means scatterplot in Figure 5a, 5c, 5e, and 5g describe 2 clusters. K-means clustering of L* and SST (Figure 5a) indicate that top cluster (blue dots) at interval 2-384 cmbsf (~0.484 – 11.015 kya) represent warmer SST and bottom cluster (red dots) at interval 384-1344 cmbsf (~11.015 – 45.524 kya) represent cooler SST. Figure 5c (cluster K-means of Cl and SST) classify that the top cluster (red dots) at interval 2-453 cmbsf (~0.484 – 12.645 kya) represents warmer SST and the bottom cluster (blue dots) at interval ~453-1344 cmbsf (~12.645 – 45.523 kya) represents cooler SST. Clustering of GA and SST (Figure 5e) describes that the top cluster (blue dots) at interval 9-530 cmbsf (~0.487 – 14.662 kya) is warmer SST and the bottom cluster (red dots) at interval 530-1344 cmbsf (~14.662 – 45.524 kya) is cooler SST. Figure 5g (MST and SST) cannot be described due to no pattern revealed.

K-means scatterplot in Figure 5b, 5d, 5f, and 5h divide into 3 clusters. Figure 5b (L*, SST, and depth) classify 3 clusters at interval 2-340 cmbsf (~0.484 – 9.980 kya) as warmer SST, 340-433 cmbsf (~9.980 – 12.153 kya) as transitional SST from cooler to warmer, and 433-1344 cmbsf (~12.153 – 45.524 kya) represents cooler SST. Cluster of L*, Cl, and GA combining with K-means clustering can divide into 2 or 3 groups. Those groups represent SST zones (cooler, transition, and warmer).

CONCLUSIONS

This study may conclude as follow:

1. SST, L*, Cl, and GA have a positive and a strong correlation, while MST has near zero and negative correlation to the others. It means L*, Cl, and GA on core 39 KL SO189/2 may represent SST variation, when MST spike against them.

2. L*, Cl, and GA, may capture ramp and spike in SST.

3. 3D scatterplot of depth (z-axis), SST (y-axis), and L*/Cl/GA combining with K-means clustering can divide into 2 or 3 groups. Those groups represent SST zones (cooler, transition, and warmer).

ACKNOWLEDGEMENTS

The Authors would like to appreciate the contribution of all crew and scientist of SO189/2 for the data availability. The Authors would like to thank the reviewer for the intense discussion that significantly enhances this paper. This study is supported by Lembaga Pengelola Dana Pendidikan Republik Indonesia (LPDP RI) grant.

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