Analyzing of the Indian Ocean Dipole (IOD) phenomena in relation to climate change in Indonesia: a review

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Abstract. IOD is another parameter that affects climate change, especially in tropical areas such as Indonesia. IOD is a global phenomenon that occurs due to differences in sea surface temperature anomalies in the western and eastern parts of the Indian Ocean. This paper aims to review several articles that discuss the Indian Ocean Dipole (IOD). The data used in this paper are the latest journals related to the IOD phenomenon in the last 10 years. From the results of the review, it is obtained a more detailed explanation of the influence of the Indian Ocean Dipole (IOD) in relation to climate change in Indonesia.

1. Introduction
Indonesia is a tropical country with only two seasons, namely the rainy season and the dry season. In general, the rainy season occurs between October-March with a peak around December to February, due to the Asian Cold Munson or western monsoon. Meanwhile, the dry season occurs between April-September with a peak around June to August, due to the Australian Cold Monsoon or east monsoon. Season in Indonesia, apart from being influenced by monsoons and local influences, is also influenced by global phenomena, including the Hadley circulation, Walker circulation, El Nino, La Nina, Indian Ocean Dipole, and others [1].

Even though the rainy and dry seasons occur periodically, the length of the season can experience shifts such as the longer the rainy season, the more the dry season will be delayed. This condition shows that the seasons in Indonesia are not only formed by the monsoon, but also by other factors that interact with the Munson to shape the season. This factor could be a global phenomenon, namely the Indian Ocean Dipole. The Indian Ocean Dipole (IOD) phenomenon is a global phenomenon that occurs due to differences in sea surface temperature anomalies in the western and eastern parts of the Indian Ocean [2].

Research on the IOD phenomenon is more focused on western Indonesia, especially Sumatra Island. In other areas, especially Java Island, it is still relatively lacking. Java Island is one of the islands which is directly adjacent to the Indian Ocean. This research was conducted to analyze the IOD phenomenon in relation to several factors such as climate change and other factors. The existence of this possibility makes researchers try to review several current and reputable journals about this global phenomenon.
2. Methods
We use several reputable journals and related to IOD phenomenon in the last 10 years. This research begins with a literature study and then selects related journals. Data analysis was carried out to determine which journals were suitable for the focus of the study. Next is the review process that can produce research results. This research procedure can be seen in Figure 1.

![Figure 1. Research procedure](image)

3. Result and Discussion
Indian Ocean Dipole or Indian Dipole Mode (IOD) is a climate anomaly that occurs due to the interaction of the atmosphere with the sea that occurs in the Indian Ocean. IOD activity can be identified by an index called the Dipole Mode Index (DMI). Dipole Mode Index is defined as the difference in sea surface temperature anomalies in the Western Tropical Indian Ocean (WTIO which is located on the tropical equator of the western part of the Indian Ocean or 50°E-70°/ 10°S-10°N) with sea surface temperature anomalies in the southeastern Tropical Indian Ocean (SETIO which is located at the tropical equator of the southeastern Indian Ocean around Sumatra and south of Java or 90°E-110°E/ 10°-equator) [2, 3].

![Figure 2. WTIO and SETIO locations](image)

IOD can also be defined as climatic deviations generated by the interaction of the ocean and the atmosphere in the Indian Ocean around the equator. This interaction produces high pressure in the eastern part of the Indian Ocean (southern part of Java and West Sumatra) which causes a flow of air masses that blow to the West. This gust of wind will push the water mass in front of it and lift the water mass from below to the surface. As a result, sea surface temperatures around the southern coast of Java...
and the west coast of Sumatra will experience a fairly drastic decrease, while near the east coast of Africa there will be an increase in sea surface temperature.

IOD is identified into two phases, namely positive and negative phases. Positive Dipole Mode is characterized by increasing sea surface temperature at WTIO and decreasing sea surface temperature at SETIO. If the sea surface temperature in WTIO is cooler than neutral while in SETIO it is warmer than neutral, then this condition will be expressed as negative Dipole Mode [2, 3].

There are 3 types of IOD based on research conducted by (Guo et al., 2015) [4], namely the first type is closely related to the development phase of El Nino / La Nina. The first type can be triggered by the Walker circulation anomaly or cross-equatorial flow anomaly. The second type develops from the warming of the entire basin (cooling) in the tropical Indian Ocean and usually occurs in the year after El Nino / La Nina and occurs due to anomalous zone sea surface temperature gradient (SST) in tropical IO. The third type does not depend on El Nino / La Nina.

The IOD phenomenon which is associated with seasonal changes in Indonesia can also be linked to various factors, including long drought, increased rainfall and fisheries.

Research on the IOD phenomenon was carried out by (Pui et al., 2012) [5]. From his research, it was found that the impact of the IOD phenomenon was drought on one side of the Indian Ocean and heavy rains on the other. Not only was Indonesia affected by the drought during the IOD Positive phase but other countries directly adjacent to the eastern part of the Indian Ocean, such as Australia were also affected. Meanwhile, Kenya and African countries bordering the western part of the Indian Ocean experience heavy rains and even floods. The impact of this IOD phenomenon does not only occur in the tropical areas of the Indian Ocean but also reaches the Mediterranean area and the Indian summer monsoon region which includes India, Pakistan, Afghanistan and Iran.

Another study was conducted by (Rahayu, N.D et al., 2018) [1] in Java Island. According to the research conducted, it was found that there was a very strong unidirectional correlation between sea surface temperature and rainfall. So that when IOD is positive, there is a decrease in sea surface temperature (SST) and it will affect the decrease in rainfall intensity as well. Likewise, the negative IOD, when there is an increase in sea surface temperature, will affect an increase in rainfall intensity. The results of this study were obtained based on data obtained from the use of several methods, namely by climatological studies and also statistical tests by sharing data from various sources.

Other research on IOD also affects fisheries. One of the IOD studies related to fisheries was conducted by (Currie et al., 2013) [6]. From the research that has been done, it is found that the increase in upwelling intensity coincided with the negative IOD phenomenon in 2010. At that time the sea surface temperature (SST) in the western tropical Indian Ocean had decreased or was lower than in the eastern part. Under these conditions, the air pressure in the eastern Indian Ocean is low, because the wind is blowing strongly from the West Indian Ocean to the East Indian Ocean. This wind that blows to the east blocks the east monsoon winds. So that it causes the weakening of the upwelling intensity in these waters. However, in 2011 there was an increase in the intensity of upwelling because it coincided with the positive IOD phenomenon. The occurrence of this phenomenon causes the air pressure in the western Indian Ocean to decrease and increase in the eastern Indian Ocean. So that the wind blows strongly from the eastern Indian Ocean to the western Indian Ocean. The wind blows with the warm water mass from east to west, this causes the slope of the water level in the eastern Indian Ocean is lower than in the western part of the Indian Ocean. The lower sea level slope in the eastern Indian Ocean is then filled with water masses from below. And that's when the upwelling intensity increases.

An increase in upwelling intensity which coincided with the positive IOD phenomenon caused an increase in chlorophyll-a content. This increase in upwelling intensity carries nutrients from the underlying layers of the waters that stimulate the growth of phytoplankton. Increasing phytoplankton levels will increase primary productivity which results in high chlorophyll-a levels in the waters. The increase in chlorophyll-a content is also thought to be due to the increase in rainfall. The increasing intensity of rainwater has resulted in increased run off of rivers around Badung Hill. Run off rivers bring nutrients into coastal waters. The increase in nutrients at the beach resulted in an increase in
phytoplankton concentrations which at the same time increased the chlorophyll-a levels in these waters [6].

Another study explaining the IOD phenomenon was carried out by (Li et al., 2003) [7]. In his research, it was explained that IOD is a dynamically coupled atmosphere-ocean mode whose instability depends on the annual cycle of the ground state. IOD has distinctive evolutionary characteristics compared to El Nino. Meanwhile, according to research (Li et al., 2016) [8] IOD is a combined air-sea climate mode that stands out from the interannual variability in the tropical Indian Ocean which is characterized by the opposite sea surface temperature anomaly (SSTA) in the eastern and eastern Indian Ocean. west, with anomalous sea level winds over the equatorial center of the Indian Ocean. When IOD is positive, sea surface temperature (SST) on the Sumatra-Java coast is lower than the western tropical Indian Ocean, and vice versa when IOD is negative. The IOD phenomenon is characterized by opposing sea surface temperature (SST) in the western Indian Ocean and tim with a vertical circulation over the equatorial Indian Ocean. When IOD was positive it resulted in two abnormally inverted walker cells being placed separately over the Indian Ocean and the west-east Pacific [15].

The IOD study was also correlated with its interaction with the El Nino Southern Oscillation (ENSO). In the research, it was shown that there is an asymmetry in the interaction between ENSO and IOD. The interaction between ENSO and positive IOD is stronger than the interaction between ENSO and negative IOD. Meanwhile, the relationship between La Nina and IOD has not been found yet [9]. The weakening of the interaction between ENSO and IOD is due to the different spatial patterns in the evolution of ENSO during the boreal spring and summer months. During the boreal spring, positive rainfall anomalies in the western Pacific off the equator weaken [10,11]. The relationship between ENSO and IOD causes variations in rainfall in Northwest Java and Makassar [12]. Apart from affecting rainfall, the relationship between ENSO and IOD also affects variations in tropical climates and their changes under the influence of global warming [13]. The relationship between ENSO and IOD also affects the Holocene variation of thermocline conditions in the eastern tropical Indian Ocean [14].

4. Conclusion

IOD is a global phenomenon that occurs due to differences in sea surface temperature anomalies in the western and eastern parts of the Indian Ocean. The IOD phenomenon which is associated with seasonal changes in Indonesia can also be linked to various factors, including long drought, increased rainfall and fisheries. In addition, the IOD phenomenon can also be associated with ENSO.

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