Modeling climate phenomenon with software grids analysis and display system in the development of the global warming module

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ABSTRACT

This study aims to model climate change based on rainfall, air temperature, pressure, humidity and wind with grADS software and create a global warming module. This research uses 3D model, define, design, and develop. The results of the modeling of the five climate elements consist of the annual average temperature in Indonesia in 2009-2015 which is between 29ºC to 30.1ºC, the horizontal distribution of the annual average pressure in Indonesia in 2009-2018 is between 800 mBar to 1000 mBar, the horizontal distribution the average annual humidity in Indonesia in 2009 and 2011 ranged between 27-57, in 2012-2015, 2017 and 2018 it ranged between 30-60, during the East Monsoon, the wind circulation moved from northern Indonesia to the southern region Indonesia. During the west monsoon, the wind circulation moves from the southern part of Indonesia to the northern part of Indonesia. The global warming module for SMA/MA produced is feasible to use, this is in accordance with the value given by the validate of 69 which is in the appropriate category and the response of teachers and students through a 91% questionnaire.

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1. INTRODUCTION

Physics is a branch of science, which studies natural phenomena, the causes of phenomena, and the effects of phenomena. Natural phenomena in climate change include rainfall, air temperature, pressure, humidity and wind. So that natural phenomena can be easily understood, it is necessary to model the phenomena through software grids analysis and display system (grADS), an interactive software that is used to easily manipulate and visualize earth science data [1], [2]. Based on the research it can be seen that, the analysis of the phenomenon of climate change and the characteristics of extreme rainfall in the city of Makassar shows that the rainfall in Makassar city is a monsoonal pattern. For 20 years (1993-2012) the extreme rainfall of Makassar city occurred in January, February, March and December. The highest extreme rainfall occurred in 2000 of 376 mm/day. The highest annual rainfall occurred in 1999 amounted to 4722 mm and the lowest rainfall occurred in 1997 amounted to 1991 mm. Makassar's lowest average monthly temperatures occur in January, February, March and December while the highest temperatures occur in May-October [3], [4]. Similar research in Bali shows that; The climate on the island of Bali in general has changed. The climate type based on Schmidt-Ferguson changes from relatively wet to rather dry. Average monthly air temperatures and monthly and annual rainfall have a tendency to increase. Wet and dry months have experienced a shift and change in number [5]. Changes in the Indonesian climate zone using koppen classification are changes in climate elements such as temperature, pressure, humidity, rain, wind to normal conditions [6]. Changes in climate elements are likely to result in changes in climate zoning [7], [8].

Therefore, this study tries to see variations in climate zoning changes in each province in Indonesia in the period 2009 to 2018 (10 years). The Köppenclimate classification is used to determine climate zoning in 33 provinces in Indonesia based on rainfall, temperature, and distribution of vegetation. From the data it is known that the average air temperature in Indonesia is always above 18ºC throughout the year, so Indonesia is certain to have climate type A.

Generally, Indonesia experiences rain throughout the year, has a tropical rain forest climate type (Af). Climate zone changes only occurred in Central Java and West Nusa Tenggara, which experienced a change from Am and Aw to Af and Am in the second period, but returned to Am and Aw in the third period. From the results of this study, it can be concluded that the variation in climatic zones in Indonesia is more influenced by rainfall than air temperature [9]. Based on field observations of physics teaching materials in SMA/MA, it was found that there was physics learning related to natural phenomena, namely global warming material contained in the basic competencies of class XI competency expectations>70% and the teaching materials used had to be integrated with scientific facts, so that students did not having difficulty analyzing a problem critically related to natural phenomena. Based on the background described above, the author feels the need to conduct research on weather phenomenon modeling with GrADS software for global warming module development. Therefore, the problem is formulated as follows; How to model climate change based on rainfall, air temperature, pressure, humidity and wind? Is the global warming module feasible to use? In order for this research to be a solution to the problems faced, the research objectives were set; 1) making climate change models based on rainfall, air temperature, pressure, humidity and wind, 2) generating and describing the feasibility of the global warming module.

2. RESEARCH METHOD

Explaining research chronological, including research design, research procedure (in the form of algorithms, Pseudocode or other), how to test and data acquisition. The description of the course of research should be supported references, so the explanation can be accepted scientifically. This research includes research and development, referring to the 4-D model that was modified into 3D consisting of define, design, and develop [10]. The study population used climate elements data for the last 10 years in the Indonesian study area. To explain the phenomenon of climated change the data is processed using GrADS software. The population to test the feasibility of the global warming module is used by students and physics teachers at MA Negeri 1 Lubuklinggau class XI. Sampling uses a purposive sampling technique, the technique of determining the sample based on the needs of the research so that the sample uses class XII science 1 students amounted to 32 students. The confidence level used is 95% and the margin of error is 5%.

2.1. Define stage

This stage is useful for determining and discussing the needs of making the global warming module and gathering various information related to the product being developed. Through interviews and field observations at MA 2 Lubuklinggau, the learning process undertaken is not in accordance with the expectations of educational competency standards with the 21st century and the 4.0 revolution era. The indicators found teaching materials used have not been integrated into actual scientific facts, so students have difficulty in analyzing the actual problems critically. One of the physics lessons that discuss natural phenomena is the global material contained in the elementary competency (KD) class XI semester 2 [11]. From the above analysis it can be concluded that the learning media consisting of the global warming module has not been suitable for use in learning, while the learning module is unsuccessful for learning [12], because it is felt necessary to create a global warming module that models without distrust using application of analysis grids software and display systems (graduates).

2.2. Design stage

The design phase includes climate elements obtained from satellite data, then processed using the GrADS software, which aims to explain the patterns of climate change. The results of data processing are presented in the form of a model. The elements of climate change include, air temperature, air pressure, humidity, rainfall and wind direction. Furthermore, the global warming module was compiled focusing on the realization of the module development design based on modeling using grADS software.

2.3. Develop stage

2.3.1. Feasibility test of the global warming module

To test the feasibility of the global warming module required expert validation, teacher and student response questionnaires, and post test cognitive learning outcomes of students after using the module. The module developed was validated by two expert lecturers, and one Physics teacher. Lecturers who validate are physics lecturers in the Physics Education study program of FKIP UNIB, while teachers who validate are physics teachers at MA Negeri 1 LubukLinggau. The validate provides a quantitative and qualitative assessment on the validation sheet. The format of expert lecturers, physics teachers is as shown in Table 1. The validation data from the validate to the module is analyzed by the average score. The percentage results are obtained through calculations with the following formula as described in (1).

$$\text{Percentage\%} = \frac{\Sigma \text{ score questionnaire rating)}}{\Sigma \text{maximum score}} x100 \quad (1)$$

where: Σ questionnaire assessment score=number of scores of answers selected, Σ maximum score=number of questionnaire items x questionnaire maximum score [13]. Product assessment qualifications can be seen in Table 2.

Table 1. Assessment of expert lecturers and teacher

Products assessed	Expert lecturer 1	Expert lecturer 2	Physics teacher	Average	Remarks
Module	65	68	75	69	worthy
Pre-test-post test Instrument	64	65	80	70	worthy

Table 2. Product rating qualifications

Achievement (100%)	Qualification	Remarks
67-100	Very Eligible	No need for revision
33-66	Worthy	Revision
0-32	Not Worthy	Revision

2.3.2. Teacher and student response analysis techniques

To see teacher and student responses to the global warming module, questionnaires and tests were used. The questionnaires were given to teachers and students, while the tests carried out by students, both questionnaires and tests before being used, were tested for validity and reliability. After the questionnaire and test instruments were declared valid and reliable, they were tested on the research subjects. Reject the research like in Table 3.

Q is a critical thinking ability test instrument to obtain quantitative data on student responses to the global warming module, using a scale of 0-100, the number of questions is 8 items followed by 32 students. Whereas a questionnaire using a list of questions was given to students and teachers who asked for approval or disagreement on each statement item submitted. Tests and questionnaires contain global warming module material which contains indicators of students' abilities in analyzing global warming symptoms, explaining the global warming process, explaining the causes of the greenhouse effect, explaining the effects of global warming and analyzing ways to overcome global warming.

2.3.3. Analysis of student responses through tests

Quantitative student response data were obtained through the analysis of increasing students' critical thinking skills using the normalized N_{gain} concept based on pretest and posttest score data. Normalized gain is the difference between the normalized pretest and posttest scores. The calculations developed by Hake (1999) in Mayub [13] as shown in (2).

$$N_{gain} = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \quad (2)$$

The N-gain score obtained was used to see the increase in critical thinking skills before being given treatment and after being given the action so that the student response score was obtained. The N-gain scores are classified into high, medium, and low categories as can be seen in Table 4. Overall student responses were analyzed using posttest scores with criteria such as in Table 5.

Table 3. Learning module trial design

Pretest	Treatment	Posttest
Q	The teacher teaches using the global warming module	Q

Table 4. N_{gain} classification

Category of gain N-gain	Remarks
0.70 <*N-gain*	High
0.30 ≤ *N-gain*≤ 0.70	Moderate
0.30>*N-gain*	Low

2.3.4. Teacher and student response

Teacher and student responses are processed by calculating the percentage of the number of respondents who give approval or disagreement with each item of the statement submitted. The calculation uses the formula PTR (%)=JR/JSR x100% [14]. PTR (%) is the percentage of respondents to a response, JR is the number of respondents in a response and JSR=the number of all respondents. Interpretation of the percentage of respondents to a response used the criteria as shown in Table 6.

Table 5. The value of the results of the student response analysis based on the post-test scores

Post test scores of students (N)	Criteria
N=0	Nobody
0 < N < 25	As a small
25 ≤ N < 50	Mostly
N=50	In part
50 < N< 75	Most of the
75 ≤ N < 100	Almost all
N=100	All of it

Table 6. Criteria for number of respondents to a response

PTR (in %)	Post test score (N)	Criteria
R=0	N=0	Nobody
0 < R < 25	0 < N < 25	As a small
25 ≤ R < 50	25 ≤ N < 50	Mostly
R=50	N=50	In part
50 < R < 75	50 < N < 75	Most of the
75 ≤ R < 100	75 ≤ N < 100	Almost all
R=100	N=100	All of it

PTR is number of respondents in a response to the program and its implementations (%)

3. RESULTS AND ANALYSIS

3.1. Modeling elements of weather change

After conducting the define phase, and the design through interviews and field observations in MAN 1 Lubuklinggau it was found that the teaching materials used were not integrated with actual scientific facts, therefore learning media in the form of the global warming module needed to be held, climate elements data were obtained from Satellite data, then processed using the GrADS software, which aims to explain patterns of climate change. The results of data processing are presented in the form of modeling.

3.1.1. Temperature

Temperature is the degree of heat of an object, after the data is processed, Figure 1 shows a graph of the temperature from 2009 to 2018 and the horizontal distribution of temperature in 2009 is given by Figure 2.

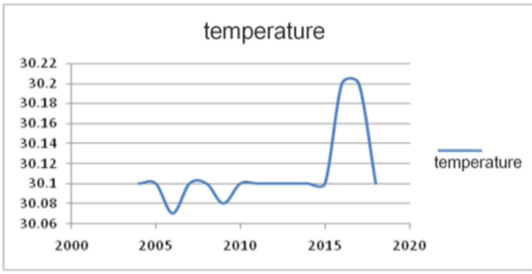


Figure 1. Air temperature in 2009-2018

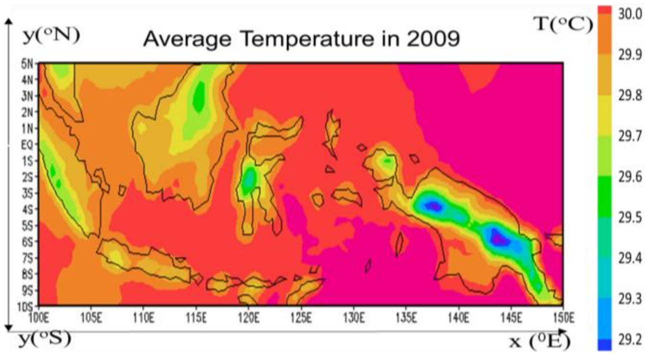


Figure 2. Horizontal distribution of the average temperature in 2009. The red color shows the maximum temperature and the purple color shows the minimum temperature

On the left y-axis shows the position of north latitude (N), equator (EQ) and south latitude (S) while the right y-axis shows temperature (°C). The x-axis shows the horizontal position on the equator (E) or the position on the east longitude. Based on Figure 2 Indonesia is located at 6°N -11°S and 95°E -141°E.

From Figure 2 it can be seen that; the horizontal distribution of the average annual temperature in Indonesia in 2009 ranged from 29.2°C to 30.1°C while the minimum temperature distribution mostly occurred in the western part of Indonesia, including Sumatra Island, Kalimantan Island, Sulawesi, Indian Ocean, South China Sea and Papua ranges from 29.2°C to 29.8°C. While the maximum temperature is spread over the Java Sea and Pacific Ocean around 30.1°C. Based on Figure 2, it can be seen that the lowest temperature in the mountains of Papua is purple, this is according to the geographical location, the West Coast of Sumatra, North Kalimantan, Sulawesi and Papua are hill and mountainous areas so that the temperature of these areas tends to be low. This finding is in accordance with the opinion of Trenberth [15] that air temperature is the degree of hot and cold air in the atmosphere and its magnitude is inversely proportional to the height of a place. Based on its distribution on earth, air temperature can be divided into two, namely horizontal and vertical distribution. The temperature of the air on the earth's surface is relative, depending on the factors that influence it, such as the duration of the sun's rays [16]. This can have a direct impact on changes in temperature in the air. This is in accordance with research that has been carried out by researchers using data from satellites.

The horizontal distribution of annual average temperatures in Indonesia in 2010-2015 and 2018 ranged from 29ºC to 30.1ºC while in 2016 and 2017 it ranged from 29.1ºC to 30.2ºC. From 2009 to 2015, the distribution of minimum temperatures mostly occurred in the western part of Indonesia, including Sumatra Island, Kalimantan Island, Sulawesi, Indian Ocean, South China Sea and Papua. While the maximum temperature is spread over the Java Sea and the Pacific Ocean. In 2016, the maximum temperature distribution occurred in almost all parts of Indonesia, including the Indian Ocean, South China Sea, Pacific Ocean, Java Sea and Banda Sea. Mean while, in 2017 the maximum temperature was only distributed in the Banda Sea and Pacific Ocean, which means that the temperature began to decrease compared to 2016. The horizontal distribution of the annual average temperature in Indonesia in 2009-2018 can be seen in Table 7.

3.1.2. Pressure

The rate of temperature change is directly proportional to the rate of change in air pressure. When the temperature of an area decreases, the air pressure will go down too. The higher a region the air pressure will decrease, this is because air has layers and each layer has a different molecular density. The higher a region, the lower the molecular density. The horizontal distribution of air pressure can be seen in Figure 3.

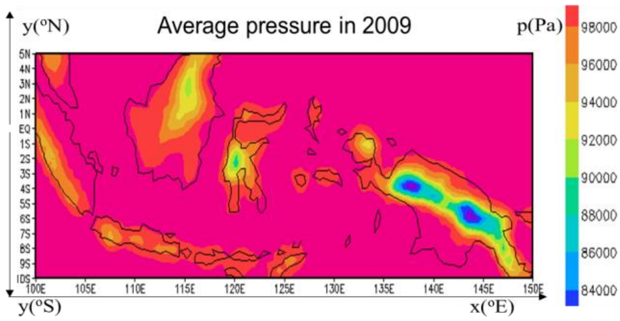


Figure 3. Horizontal distribution of annual average pressure in 2009

On the left y-axis shows the position of N, EQ and S while the right y-axis shows pressure (Pa). The x-axis shows the horizontal position on the E or the position on the east longitude. Based on Figure 3 the horizontal distribution of the annual average pressure in Indonesia in 2009 ranged from 80000 Pa to 100000 Pa or 800 mBar to 1000 mBar, as well as for 2010-2018 it was relatively the same. This difference in pressure causes wind to occur. This finding is in line with the opinion of experts who say that; moving air caused by rotation of the earth and also because of differences in air pressure around it. The wind moves from a place of high pressure to low pressure air [17]. This is consistent with what researchers did in modeling the average annual pressure above. Based on color, the West Coast of Sumatra, North Kalimantan, Sulawesi and Papua have low temperatures so that the air pressure in these areas is also low. On the West Coast of Sumatra, air pressure ranges from 960 mBar-920 mBar, in Kalimantan it ranges from 960 mBar-900 mBar, in Sulawesi it ranges from 960 mBar-880 mBar and in Papua it ranges from 960 mBar-800 mBar. Furthermore, the horizontal distribution of annual average pressure for 10 years (2009-2018) can be seen in Table 8.

3.1.3. Humidity

Air humidity is the level of wetness of the air, the amount of water vapor in the gas mixture between air and water vapor. The amount of water vapor in the air is only a small part of the atmosphere, about 2% of the mass. The unit of humidity commonly used is relative humidity (RH). RH is a unit of measurement that represents the number of water droplets in the air at a certain temperature compared to the maximum number of water droplets that can be contained in the air at that temperature. RH is expressed as a percentage value. But this amount is not constant, varies between 0-5% [18]. This is consistent with the results of the study that we can see in Figure 4.

Table 7. Horizontal distribution of the average annual maximum temperature and minimum annual average temperature in Indonesia in 2009-2018

No	Year	Temperature (°C)
1	2009	29.0-30.1
2	2010	29.0-30.1
3	2011	29.0-30.1
4	2012	29.0-30.1
5	2013	29.0-30.1
6	2014	29.0-30.1
7	2015	29.0-30.1
8	2016	29.1-30.2
9	2017	29.1-30.2
10	2018	29.0-30.1

Table 8. Horizontal distribution of annual mean pressure over 10 years (2009-2018)

No	Year	Average Pressure (Pa)
1	2009	80000-10000
2	2010	80000-10000
3	2011	80000-10000
4	2012	80000-10000
5	2013	80000-10000
6	2014	80000-10000
7	2015	80000-10000
8	2016	80000-10000
9	2017	80000-10000
10	2018	80000-10000

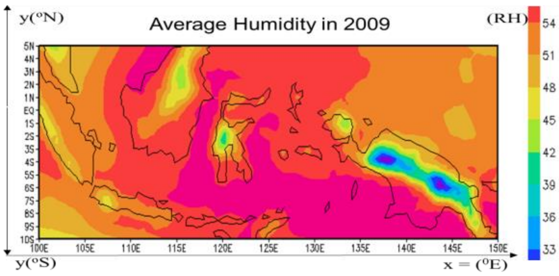


Figure 4. Horizontal distribution of annual average humidity years 2009

On the left y-axis shows the position of N, EQ and S while the right y-axis shows RH. The x-axis shows the horizontal position at the E or the position on the east longitude. Based on Figure 4, the moisture distribution has the same pattern as the temperature and air pressure distribution. When the temperature and pressure decrease, the humidity decreases and vice versa when the temperature and pressure increase, the humidity rises. Horizontal distribution of annual average humidity in Indonesia in 2009, 2010 and 2011 ranged between 27-57, 2012-2015, 2017 and 2018 ranged from 30-60 and in 2016 ranged from 30-57 RH, see Table 9. The minimum value of air humidity is in the West Coast of Sumatra, North Kalimantan, Sulawesi and Papua. Air humidity in the West Coast region ranges from 45-51, North Kalimantan ranges from 39-51, Sulawesi ranges from 45-51 and Papua ranges from 33-51 (air humidity unit). The high humidity of the sea area is due to the very high evaporation process that occurs above the sea. This is supported by the theory that under normal conditions, temperature, air pressure and humidity tend to be comparable [19].

3.1.4. Rainfall

Rainfall is the amount of rain water that falls at a certain time, its measurement uses the unit height of millimeters (mm) above the horizontal ground surface which is assumed to not occur infiltration, run off, or evaporation. The amount of rainfall is the volume of water collected on the surface of a flat area at a certain period (daily, weekly, monthly, or yearly). Rainfall is also interpreted as the height of rain water that is collected in a flat, non-evaporating, non-absorbing and non-flowing place [20]. The distribution of rainfall obtained in 2009 is shown in Figure 5. While the distribution of the average rainfall in 2009 to 2018 ranges from, in 2009 30 ml/sec-57 ml/sec, in 2010 33 ml/sec-43 ml/sec, in 2011 27 ml/sec-57 ml/sec, in 2012 and 2013 33 ml/s-60 ml/s and from 2014 to 2018, 30 ml/c-60 ml/s, can be seen in Table 10. Rainfall is high in the marine and southern regions of Indonesia.

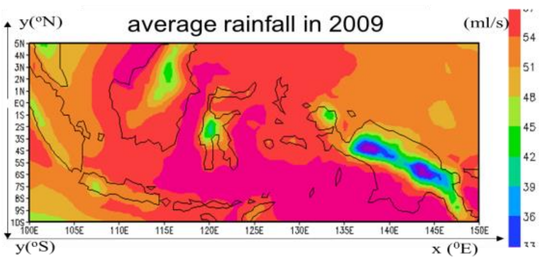


Figure 5. Horizontal distribution of annual average rainfall years 2009

On the left y-axis shows the position of N, EQ and S while the right y-axis shows rainfall (ml/s). The x-axis shows the horizontal position at the E or the position on the east longitude.

Table 9. Horizontal distribution of annual average humidity for 10 years (2009-2018)

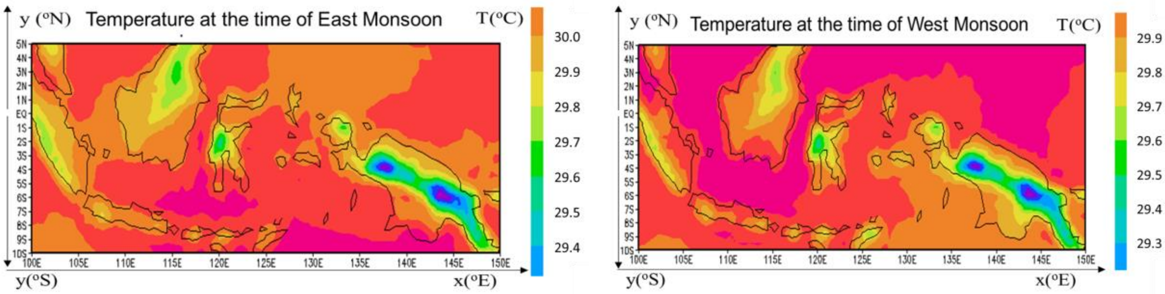
No	Year	Average Humidity (RH)
1	2009	27-57
2	2010	27-57
3	2011	27-57
4	2012	30-60
5	2013	30-60
6	2014	30-60
7	2015	30-60
8	2016	30-57
9	2017	30-60
10	2018	30-60

Tabel 10. Horizontal distribution of annual average rainfall for 10 years (2009-2018)

No	Year	Average Rainfall (ml/s)
1	2009	30-57
2	2010	33-43
3	2011	27-57
4	2012	30-60
5	2013	30-60
6	2014	30-60
7	2015	30-60
8	2016	30-60
9	2017	30-60
10	2018	30-60

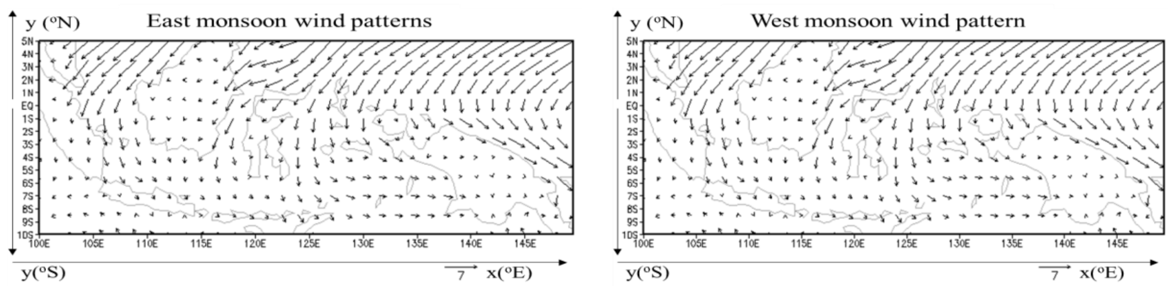
3.1.5. Wind directions

During the eastern monsoon (December, January, February), temperatures in the northern part of Indonesia (South China Sea, Pacific Ocean, Sumatra, Kalimantan and Sulawesi region) ranged from 29.7°C to 30.1°C lower than the southern part of Indonesia. which has a maximum temperature of 30.2°C. At the time of the West Monsoon (June, July, August) the maximum temperature is in the North of Indonesia (Java Sea, South China Sea, Pacific Ocean) with a temperature of 30.2°C and the temperature of the South Indonesia region of 29.8°C. The temperature distribution at the time of East Monsoon and West Monsoon can be seen in Figure 6 (a) and Figure 6 (b). The 2016 East and West Monsoon Circulation Patterns can be seen in Figure 7 (a) and Figure 7 (b).



(a) (b)

Figure 6. Temperature during; (a) the east monsoon in 2016, (b) the west monsoon in 2016



(a) (b)

Figure 7. Wind circulation patterns during; (a) the east monsoon in 2016, (b) the west monsoon in 2016

The temperature distribution affects the circulation pattern, the amount of rainfall in an area, because temperature affects the humidity of the air, so that when the water vapor in the clouds reaches the maximum amount, it will fall to the earth to become rain, therefore the rate of humidity is proportional to the amount of rainfall. The sea area plays a role in the high humidity value. In the east season (December, January, February) the humidity in Indonesia ranges from 33-60 and is scattered throughout Indonesia. From a study it was found that; climate change which does not change the climate which consists of temperature, pressure, humidity, rain, and wind becomes normal conditions. This fact is proven from 102 years of air temperature data, showing that; Throughout the year, the average air temperature in Indonesia is always above 25.4°C. The average temperature increased from 25.6°C in the early 1900s to around 26°C by the end of the 20th century. The first period (1901-1934) the average was 25.8°C. The second period (1935-1968) had an average of 25.7°C. While the third period (1969-2003) the annual average air temperature rose to above 26°C.

In the first period there was a continuation pattern between the test rainfall and SOI, after a positive SOI (El Nino) event, followed by a decrease in rainfall and a negative SOI (La Nina), followed by an increase in rainfall. In the second period, the SOI value changes very often so that the rainfall anomaly graph fluctuates. In the third period, extreme ENSO events occurred more frequently and were followed by rain. The average air temperature in Indonesia is always above 18ºC throughout the year, so Indonesia already has a class A climate type. Therefore, regions in Indonesia are included in the Af, Am or Aw subgroups. Indonesia's air temperature has increased a maximum of 0.7ºC per year, while the maximum increase in rainfall is 565 mm per year. Most of Indonesia experiences rainfall throughout the year or has a tropical rainforest climate type (Af), except in southern Indonesia which is relatively drier or Munson climate type and savanna climate (Am and Aw). Climate zoning changes in the second period which is different from the first and third periods. There are similarities and differences between previous studies and this study, the same thing lies in the variables studied, namely rainfall and temperature. The difference lies in the method used, the previous study used the Köppen climate classification [21], while this study used the GrADS software. Previous researchers used data from the climatic research unit (CRU) while this study used data from satellite data. Based on previous research, rainfall is a climatic element that is very influential on climate change [22], [23]. Meanwhile, this study found that all elements of climate have a significant influence on climate change, but some have a large effect and some have a small effect. The five elements of climate are interrelated, it can be seen from the color of the region in the modeling. The temperature in North Kalimantan, West Coast Sumatra and Sulawesi ranges from 29.5ºC to 29.8ºC. The temperature in Papua ranges from 29.1ºC to 29.8ºC. The regions of North Kalimantan, the West Coast of Sumatra, Sulawesi and Papua are hilly and mountainous areas with relatively low temperatures. The distribution of the average rainfall for 20 years (2009-2018) can be seen in Table 11. While the graph of max and min rainfall looks like in Figure 8.

Table 11. Distribution of average rainfall in 2009 to 2018

No	Year	Average rainfall (ml/sec)
1	2009	30-57
2	2010	33-43
3	2011	27-57
4	2012	33-60
5	2013	33-60
6	2014-2018	30-60

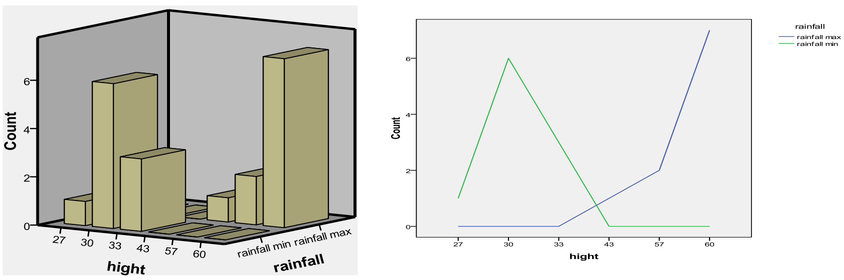


Figure 8. Graph of max rainfall and min

Humidity in Indonesia during the east season between 33-60 and spread throughout Indonesia, this is due to the influence of climate elements on climate change, but the effect is uneven, because some have a big influence and some have an effect small, so it can be seen that the color of the region in the modeling is relatively different. Based on the research it was found that; (1) The annual average temperature in Indonesia in 2009-2015 and 2018 ranged from 29ºC to 30.1ºC while in 2016 and 2017 it ranged from 29.1ºC to 30.2ºC increased by 0.1ºC. This is due to Indonesia's position which allows it to receive more sunlight than other regions. Topography also greatly affects temperature. The higher the area, the lower the temperature. The horizontal distribution of mean annual pressure in Indonesia in 2009-2018 ranges from 80000 Pa to 100000 Pa or 800 mBar to 1000 mBar. On the West Coast of Sumatra, the air pressure ranges from 960 mBar-920 mBar, the Kalimantan area ranges from 960 mBar-900 mBar, the Sulawesi region ranges from 960 mBar-880 mBar and the Papua region ranges from 960 mBar-800 mBar. The temperature distribution affects the surface pressure distribution, because the rate of change in pressure is proportional to the rate of change in temperature. the factors affecting the air pressure distribution are the same as those affecting the temperature. The higher an area, the lower the air pressure, this is because air has layers and each layer has a different molecular density. This is what causes climate change that is not the same in every region, (2) The horizontal distribution of average annual humidity in Indonesia in 2009 and 2011 ranges from 27-57, 2012-2015, 2017 and 2018 ranges from 30-60 and in 2016 ranges from 30-57 RH. The humidity in the West Coast ranges from 45-51 RH, North Kalimantan ranges from 39-51 RH, Sulawesi ranges from 45-51 RH and Papua ranges from

33-51 RH. The sea area has high air humidity which causes climate change. because the evaporation process that occurs above the sea is higher, (3) Rainfall in 2009 30 ml/s- 57 ml/s, in 2010 33 ml/s-43 ml/s, in 2011 27 ml/s-57 ml/s, in 2012 and 2013 33 ml/s-60 ml/s and from 2014 to 2018 30 ml/s-60 ml/s. High rainfall in the sea and southern regions of Indonesia. Because the distribution of rainfall is directly proportional to the distribution of air humidity, (4) The difference in temperature between northern Indonesia and southern Indonesia during the east season and the west season. In the east season, the wind circulation moves from northern Indonesia to southern Indonesia. In the west monsoon, the wind circulation moves from southern Indonesia to northern Indonesia, this is due to the fact that the wind is an air mass moving from low-temperature areas to high-temperature areas. Based on the research results, it is known that the weather characteristics in 2009-2018 are shown in Table 12.

Table 12. The weather characteristics of 2009-20018

No	Year	Average Temperature (ºC)	Average Pressure (mBar)	Average Humidity (RH)	Average Rainfall (ml/s)
1	2009	29.0-30.1	800	27-57	30-57
2	2010	29.0-30.1	800	27-57	33-43
3	2011	29.0-30.1	800	27-57	27-57
4	2012	29.0-30.1	800	30-60	30-60
5	2013	29.0-30.1	800	30-60	30-60
6	2014	29.0-30.1	800	30-60	30-60
7	2015	29.0-30.1	800	30-60	30-60
8	2016	29.1-30.2	800	30-57	30-60
9	2017	29.1-30.2	800	30-60	30-60
10	2018	29.0-30.1	800	30-60	30-60

Based on Table 12, it can be seen that the weather conditions in Indonesia for 10 years from 2009-2018 are relatively stable, including the wind direction, this can be used by farmers and fishermen as a guide for starting the planting period and time to go to sea, although there are certain exceptions (anomalies) when changes seasons that need to be anticipated in advance.

3.2. Feasibility of the global warming module

3.2.1. Module format

The module format consists of the title page, module identity, preface, table of contents, table list, list of pictures, module description, module instructions, competencies achieved, concept map, learning activities, evaluation, bibliography.

3.2.2. Module validation results

Based on Tables 13 and Tables 14, it can be seen that; the average score given by lecturers and teachers to the global warming module and the pre-test post-test material, respectively 69 and 70, are in the very eligible category.

Table 13. Assessment by lecturers and teachers

Products assessed	lecturer 1	lecturer 2	Physics teacher	Average	Remarks
Module	65	68	75	69	Very Eligible
a matter of pretest-posttest	64	65	80	70	Very Eligible

Table 14. Product rating qualifications

Achievement (100%)	Qualification	Remarks
67-100	Very Eligible	No need for revision
33-66	Worthy	Revision
0-32	Not feasible	Revision

3.2.3. Teacher and student responses

Student response analysis is obtained by using post-test questions. Analysis of the feasibility of the module to improve students' thinking abilities is determined by counting the number of students who achieved the highest post-test score. The value of the results of the analysis of student responses based on the post-test scores can be seen in Table 15. While the analysis of student responses based on increasing students' critical thinking skills can be seen in Table 16.

Table 15. Value of the results of the student response analysis based on the post-test scores

No question	Value (%)	Remarks	No question	Value (%)	Remarks
1	81.2	Almost all of it	5	78.1	Almost all of it
2	71.9	Most of the	6	65.6	Most of the
3	71.9	Most of the	7	87.5	Almost all of it
4	68.8	Most of the	8	75.0	Almost all of it

Based on the value of the highest student response seen in question number 7 with a value of 87.5 with the criteria that almost all students responded to the material that had been given while the lowest student response score was located in question number 6 with a value of 65.6. The criteria for a meaningful value most of the students responded to the material that had been given. Thus, it can be stated that almost all students respond very well to the modules used in learning. In addition, it was also found that; Based on the concept of normalized N_{gain} value using pre-test and post-test score data, the average N_{gain}value is 0.7025, which means that the student's response to module use is in the high category.

Table 16. Analysis of student responses based on the improvement of students' critical thinking skills

No	Pre test		Posttest		Value *N-gain*	
	score	interpretation	score	interpretation	score	interpretation
1	14.0	low	81.2	high	0.78	high
2	15.4	low	71.9	moderate	0.67	moderate
3	16.3	low	71.9	moderate	0.64	moderate
4	14.4	low	68.8	moderate	0.64	moderate
5	14.0	low	78.1	high	0.75	high
6	15.0	low	65.6	moderate	0.59	moderate
7	15.0	low	87.5	high	0.85	high
8	14.0	low	75.0	moderate	0.70	moderate
average	14.7	low	75.0	high	0.7025	high

3.2.4. Teacher and student response analysis obtained by using a questionnaire

Table 17 shows the value of teacher and student responses on average by 91.0% with the interpretation "almost entirely", it can be concluded that, the response of teachers and students to the global warming module said that; almost all teachers and students agree and are eligible to use the global warming module. Module feasibility analysis to improve students' thinking abilities is determined by counting the number of students who achieve the highest post-test scores. Based on the highest student response value seen in problem number 7 with a value of 87.5 with the criteria almost all students respond to the material that has been given while the lowest student response value lies in problem number 6 with a value of 65.6 criteria value of most students respond to the material that has been given.

Table 17. Value data response of teachers and students based on questionnaires

No question	Teacher and student	
	JR in (%)	Criteria
1	93.8	Almost all
2	90.6	Almost all
3	89.8	Almost all
4	88.3	Almost all
5	92.9	Almost all
6	86.7	Almost all
7	95.3	Almost all
8	90.6	Almost all
average	91.0	Almost all

Thus, it can be stated that almost all students respond very well to the modules provided by researchers. This also shows that students are able to think critically. This finding is in line with theories that say critical is a persistent effort to test something that is believed to be true or knowledge with supporting evidence so that further conclusions can be drawn right. Critical thinkers can produce important questions and problems, formulate clearly, gather and assess relevant information, use ideas that are abstract, think with a broad view and communicate effectively [24], [25]. Thus, it can be stated that the students 'post-test scores using the global warming module show that students' critical thinking skills are very good, can be applied to the learning of global warming material. This finding is in line with other findings which say Critical thinking enables students to study problems systematically, face millions of challenges in an organized way, formulate innovative questions, and design solutions [26], [27]. Cognitive skills, critical thinking skills, scientific work skills, and students' scientific attitudes can be improved through research methods in learning-based research [28], [29].

4. CONCLUSION

Climate change based on rainfall, air temperature, pressure, humidity and wind can be modeled through the grADS software and the modeling results show that weather conditions in Indonesia for 10 years from 2009-2018 are relatively stable, including wind direction. This can be used by farmers and fishermen as a guideline for starting the planting period and the time to go to sea, although there are some exceptions (anomalies) when changes in seasons need to be anticipated in advance. Extreme climate change (anomaly) that occurs every year is not always fixed in time, sometimes there is a shift in time, this can be used as a guide in carrying out activities related to the activities of farmers and fishermen. The climate change modeled by grADS can be used as material to create a module of global warming that is suitable for learning, it can be seen from the findings, which states that; based on the value given by validate 1, 2 and validate 3, which are respectively 65 (feasible), 68 (feasible) and 75 (very feasible), with an average of 69 feasible categories, the global warming module is feasible to use. The global warming module can improve students' critical thinking skills, it can be seen from the post-test score > the pre-test average (0.6-0.9 > 0.19-0.24), which means that it has increased from what was originally within the criteria low to medium and high criteria. The global warming module has received a good response from both teachers and students. This can be seen from the highest teacher and student response scores on question number 7 with a value of 87.5, which means that almost all students and teachers respond to the material that has been given, while the teacher and student responses are the lowest on question number 6 with a value of 65.6 which means most of the participants students and teachers respond to the material that has been given.

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