SUNSHINE DURATION AND DIURNAL TEMPERATURE RANGE AND ITS RELATION TO CLIMATE CHANGE IN PONTIANAK

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ABSTRACT

Sunshine Duration (SD) has an important role in climate change or the weather on the earth. Climate change can be indicated by changing SD values (dimming/brightening) in recent decades. SD and diurnal temperature range (DTR) analysis needs to be done to find out how significant the impact of climate change. The daily dataset from 1981-2019 of SD, DTR, T_{mean}, T_{max}, T_{min}, and rainfall in Pontianak, West Kalimantan, is analyzed with Continuous Wavelet Transform (CWT) and wavelet coherence (WTC). Results of CWT using the Morlet wavelet SD have a dominant period of 8-16 months. DTR has a dominant period of 8-16 months and 32-64 months. The increase in SD indicates that Pontianak is in a brightening period caused by changes in the characteristics of clouds and aerosols. It causes an increase in the amount of solar energy reaching the earth's surface. Climate change has been detected by the decrease in DTR. A negative correlation was found between DTR and SD (r = -0.80). DTR is a very good indicator of climate change because of its sensitivity to radiative energy balance. Changes in SD have a significant impact on T_{mean}, T_{max}, and T_{min}. The increase of T_{min}, faster than T_{max}, causes a decrease in DTR. T_{min} is predicted to be higher. T_{mean} and T_{max} have dominant periods of 8-16 months, while T_{min} has dominant periods of 12-20 months and 32-64 months. The increase in temperature detected during this period is associated with peatland forest fires in Kalimantan. This condition occurs due to the effect of the brightening period and increasing concentrations of greenhouse gases in the atmosphere. Rainfall is detected in the period of 4-8 months and 8-16 months. The drought associated with the El Nino event resulted in a large amount of rainfall deviation from normal.
Keywords: Sunshine duration, diurnal temperature range, climate change, CWT, WTC.

1. Introduction

The sunshine duration (SD) can be attributed to climate change [1]. SD is an insolation force that exceeds a threshold value of 120 W/m^2 [2]. Climate change is becoming a very important and widely discussed topic. There are several things that can be used as a reference to see the characteristics of variability and climate change. The most likely to be felt are changes at the local level, such as an increase in the frequency of extreme events, changes in rainfall, and changes in daily minimum and maximum temperatures above the average [3,4,5].

The uneven reception of the amount of solar radiation for each surface of the earth causes differences in climate between one region and another. SD is one of the indicators of solar energy that plays an important role in the climate or weather on the earth. Today, the issue of world climate change is linked to changes in SD values in the dimming/brightening period of recent decades [6,7]. Diurnal Temperature Range (DTR) is an important indicator of climate change due to its sensitive nature to changes in the radiant energy balance [8,9]. DTR is the difference between the daily maximum temperature (T_{max}) and the minimum temperature (T_{min}) [10]. In most areas of the world, a faster increase in T_{min} than T_{max} will lead to a decrease in DTR. The increase in temperature is thought to be due to the influence of the brightening period and an increase in the concentration of greenhouse gases in the atmosphere. The dimming period, the DTR value is greater than during brightening period. This indicates that during the brightening period, the difference between T_{max} and T_{min} was not very large. The reduction in DTR observed over the last century is enormous and unlikely due to natural variability alone [11].

SD and DTR have a strong correlation [12,13]. The larger SD and higher measured temperature with cloud cover can make low temperatures on that day. Temperature, cloud cover, relative humidity, duration of solar irradiation, and precipitation data are used in estimating the solar energy radiation received by the earth [14]. In the context of climate change, one of the most obvious consequences is a change in the water cycle that essentially affects precipitation patterns. Cloud cover and rainfall were identified as the main causes of DTR reduction. Clouds and rainfall can reduce T_{max} by reducing solar radiation to the earth's surface during the day and increasing T_{min} at night, thus affecting DTR. Atmospheric circulation, greenhouse gases, aerosols, and land cover/land-use, can also impact DTR.

DTR is considered an indicator of climate change because of its sensitivity to radiant energy balance

[11]. States that DTR changes are identifiable characteristics of recent climate change and also provide a diagnostic index for evaluating global climate models. The trend of global average warming on land has been attributed to asymmetric changes in T_{min} and T_{max}. Therefore, DTR has decreased globally over the past fifty years due to relatively stronger increases in daily minimum temperature (T_{min}) than daily maximum temperature (T_{max}). T_{min} is closely related to the flux of longwave radiation, whereas T_{max} is largely determined by shortwave radiation. Therefore, the DTR trend is useful for diagnosing recent climate change.

Pontianak is located in West Kalimantan and crossed by the equator. It has a wet tropical climate, with rainfall evenly distributed throughout the year, with peak rain occurring in March and October. The average rainfall ranges from 200 to 350 mm per month, air pressure ranges from 1,010 to 1,012 mb per month, and solar irradiation ranges from 40 to 60 percent per month [15]. Kalimantan is an island that has vast peatlands, and the stability of these peatlands has important implications for climate change. Tropical peatlands will contribute significantly to global carbon emissions in the future, except by mitigation, restoration, and rehabilitation.

Previous study shows that the average duration of solar irradiation in the Pontianak area is 8 hours [16]. The average solar energy potential reaches more than 60%, and the duration of solar irradiation is about 2-4 hours per day. Based on data between 1990 and 2019, there is a duration anomaly of solar irradiation in West Kalimantan in the dry season of 1997 due to forest and land fires corresponding to El Niño events [17]. The annual average SD value at Supadio Pontianak station in 2010-2019 was higher than the previous year.

This study aims to investigate the relationship between SD and DTR on climate change in Pontianak, Indonesia, using Continuous Wavelet Transform (CWT) and Wavelet Coheren (WTC) analysis.

2. Methods

We used secondary data from the Supadio Pontianak Meteorological Station (World Meteorological Organization this station 96581), downloaded from www.ogimet.com. We used daily data of SD, T_{max}, T_{min}, T_{mean}, DTR, and rainfall during 1981-2019. The daily data is converted into monthly average and annual average data. Monthly and annual average data is used to identify the maximum and minimum distribution of data fluctuations and what causes those fluctuations to occur. Furthermore, data analysis is carried out by wavelet transformation.

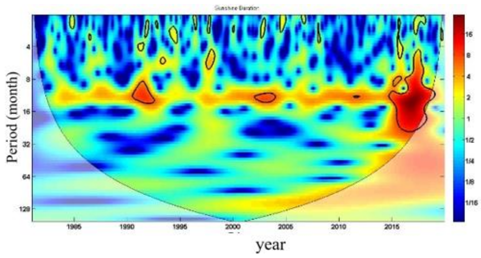
In recent years, signal processing methods have been widely used in environmental studies, especially in atmospheric science and hydrology. More recently, wavelet analysis techniques analyzed data for local and global climate change and revealed the active frequencies in the time series and their changes over time [18].

Periodicity plays an important role in climate reconstruction. The periodicity of time series in climatology has been widely analyzed using the wavelet method [19]. This periodicity has been recognized as an important component in predicting and recommending adaptation to future climate change both regionally and globally. Wavelet analysis includes Continuous Wavelet Transform (CWT) and Wavelet Coheren (WTC).

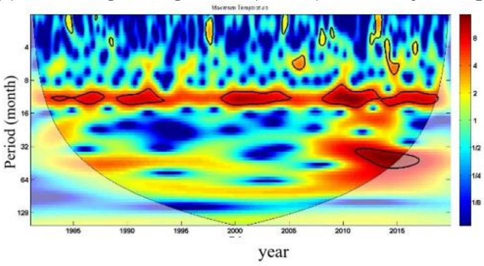
Wavelet transformation is a spectral analysis method that can analyze non-stationary time series (e.g., atmosphere and hydrology) by analyzing trends and dominant time scales that affect data so that it is useful for interpreting cyclical patterns in environmental data [20]. A wavelet transformation is the convolution of a wavelet function with a signal. A wavelet transformation essentially quantifies the local match of a wavelet to its signal. If the wavelet corresponds to the shape of the signal well at a certain scale and location, then the transformation value obtained will be large and vice versa. CWT spectral wavelets exhibit intermittent oscillations of the time series. Wavelets can be characterized by functions localized in time and frequency. The variation of wavelet transformations depends on dilation (related to frequency information) and translation (related to time information). Wavelet Coherence (WTC) between two CWT can determine significant coherence between two-time series. Using WTC will obtain information about phase differences when using complex wavelet functions. The phase difference can be calculated using the imaginary part and the real part of the Cross Wavelet Transform (XWT) separately [21]. A positive (negative) correlation between two-time series in the time-frequency domain shows an in-phase (out-phase). The phase information will be plotted on wavelet coherence and indicated by the direction of the arrow in radians.

3. Result and Discussion

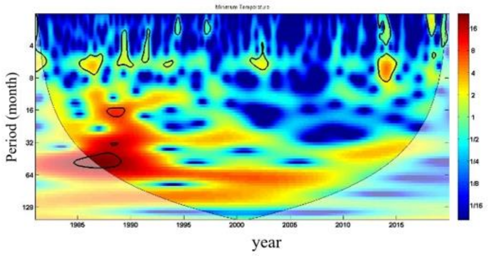
Wavelet analysis is a method commonly used to study periodicity in climate time series. The CWT with Morlet wavelet as the mother function (Figure 1a-f) has produced strong results in climate analysis. In this analysis, the CWT was used to calculate the wavelet spectrum at the time-frequency space in Pontianak, West Kalimantan in 1981-2019. The x axis shows the time domain while the y axis shows the period (month).



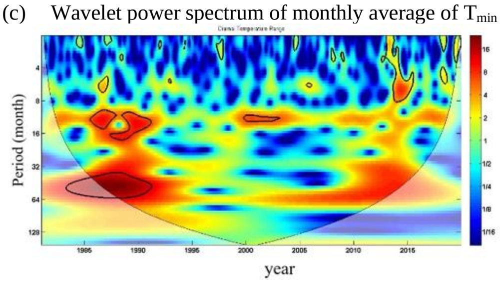
(a) Wavelet power spectrum (Morlet) of monthly average of SD



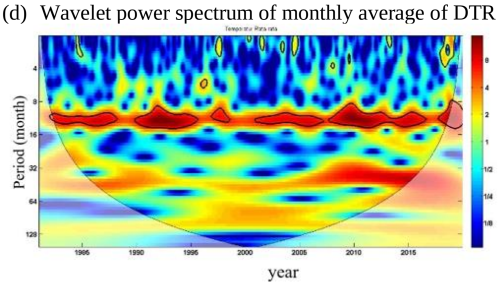
(b) Wavelet power spectrum of monthly average of T_{max}



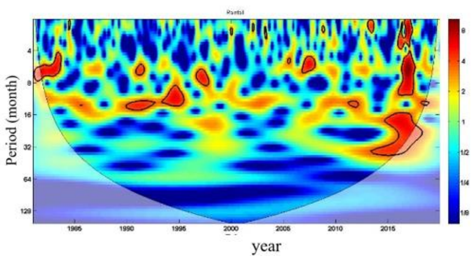
(c) Wavelet power spectrum of monthly average of T_{min}



(d) Wavelet power spectrum of monthly average of DTR



(e) Wavelet power spectrum of monthly average of T_{mean}



(f) Wavelet power spectrum of monthly average of rainfall

Figure 1. Wavelet power spectrum (Morlet) from the Continuous Wavelet Transform (CWT) of (a) SD, (b) T_{max}, (c)T_{min}, (d) DTR, (e) T_{mean} and (f) rainfall data from 1981-2019.

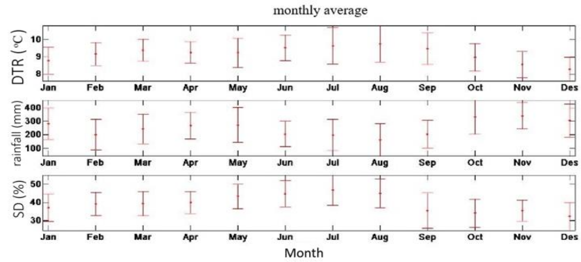


Figure 2. Distribution of the monthly average of SD in 1981-2019.

Wavelet power spectrum (Morlet) from the Continuous Wavelet Transform (CWT) will show the intermittent oscillation of the time series. Figure 1a-f shows the power (absolute value square) of the wavelet transformation for the data of each of the respective parameters on this study. The absolute value of this square gives information about the relative force on a given scale and time. Figure 1a-f shows a significant peak at a level of certainty above 95% for the global wavelet spectrum, assuming red-noise, depicted by the Cone of Influence showing the area in the time-frequency space. Because it relates to a limited time line, errors will occur at the beginning and end of the wavelet power spectrum.

Monthly and annual SD distribution (1981-2019). SD is the energy of the solar radiation that reaches the earth. The intermittent oscillation of the SD (Figure 1a) with a period of 4-8 months (centered on 6 months) was significant in 1997, in the period of 8-16 months (centered on 12 months) was significant in the years 1900-1992 and 2002-2003. Then, the oscillation with a period of 6-24 months (centered on 12 months) was significant in 2015-2017. It can be said that the SD time series has strong annual signals and fluctuations.

Distribution of the monthly average SD in 1981 to 2019 can be seen in Figure 2. Figure 2 shows that in general, the lowest monthly SD rate in Pontianak with around 32% occurred in December. Meanwhile, the highest monthly SD rate with about 47% occurred in July. On the other hand, the annual SD rate in Pontianak is shown in Figure 3. The lowest annual SD value for the period of 1981 to 2019 was 1,357.7 hours in 2017, while the highest annual SD value with 2,128 hours occurred in 2019. The lowest monthly average was found in July 1991 at 36.2 hours.

The lowest recorded SD was in 1997 (1.554.4 hours per year) since 1991-1998. SD declines also occurred in 1999-2003. In 2015, the calculated SD reached only 1,799.5 hours while in 2014, it reached 2,009.5 hours per year. SD increased in 1991-1992 from 1,411.6 hours per year to 1,723 hours per year. A sharp increase was recorded in 2010-2011 by 1,718.8 hours/year to 2,012.6 hours per year. However, generally SD experienced an increase from 1981-2019 (Figure 3).

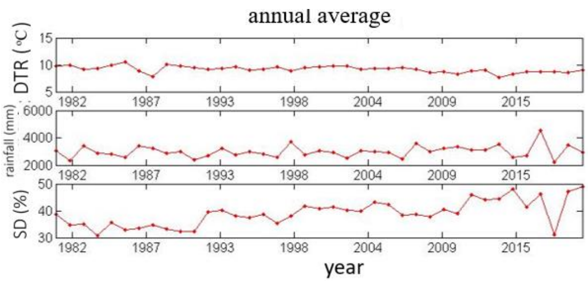


Figure 3. Distribution of annual average of SD, rainfall and DTR in 1981-2019.

This is the first study which discusses the duration of solar irradiation and diurnal temperature range on climate change in Pontianak, Indonesia. DTR is sensitive to changes in the radiant energy balance, which makes DTR an important indicator of climate change. A negative correlation was obtained between DTR and SD in Pontianak during the observed time series (r = -0.80). The increase in SD value in 1981-2019 indicates that Pontianak is in a brightening period (Figure 3) caused by changes in the characteristics of clouds and aerosols. This brightening leads to an increase in the amount of solar energy reaching the earth's surface. Changes in SD have a significant impact on T_{mean}, T_{max}, and T_{min} because temperatures are sensitive to changes in SD. A faster increase in T_{min} than T_{max} causes a decrease in DTR.

Climate change can be identified by the average change or variability of its traits over a long period of time, usually decades [22]. Weather is defined as a nonlinear dynamic system of atmosphere, the state of air in the atmosphere at a particular time and place that is erratic and variable in nature, while climate is the average state of weather. The climate is quite stable and predictable.

Changes in the duration of solar irradiation. The change in the average value of the SD is clearly visible in the time series analysed in 1981-2019. Generally, the annual and monthly periods are divided into four periods: 1981-1990, 1991-2000, 2001-2010 and 2011-2019. The average value of SD in Supadio Pontianak increased in the period of 2011-2019 compared to the previous period which reached 2.099.4 hours per year (Figure 4a). The change in the value of the SD monthly rate has a pattern similar to the annual average (Figure 4b). The monthly average SD scores in periods of 1981-1990, 1991-2000, 2001-2010 and 2011-2019 were 124.14 hours, 139.49 hours, 145.91 hours and 160.88 hours respectively. Then, it can be inferred that the duration of solar irradiation was increasing.

In addition, there was a sudden decline in SD values that began in 1986-1991, and then in 1994-1998. According to the research [17], it is mentioned that the land coverage declined drastically between 1991 and 2001 in the area of Kubu Raya where dense forest areas were transformed into people's settlements and forests [23]. The condition is believed to be the cause of the change in SD values in Supadio Pontianak.

From the SD time series of 1981 to 2019, there was a period of enlightenment that can be described as an increase in the value of SD. It is known that the period of inflation and enlightenment is associated with the interaction of solar radiation primarily with aerosols and clouds as they pass through the Earth's atmosphere on their way to the surface of the Earth. Therefore, the cause of the change in the amount of solar radiation measured on the earth's surface over the years is related to the Earth's atmospheric system (atmospheric circulation).

Many scientists [24] and [25] mentioned that the 1960-1985 period of global dimming due to measurements carried out during that time at many locations around the world showed a decrease in the intensity of solar radiation of about 4%. The decrease in the amount of solar radiation received on the Earth's surface may have been associated to the accumulation of black carbon and aerosols in the atmosphere, both of which are products of human activity, as the highest concentrations of such substances are found in urban areas. In addition, changes in cloud characteristics resulted in an increase in the amount of solar energy reaching the Earth's surface from some regions of the world. A study of this global climate model found that greenhouse gases, aerosol sulfates, and solar variability may all have important roles in the climate change of the twentieth century.

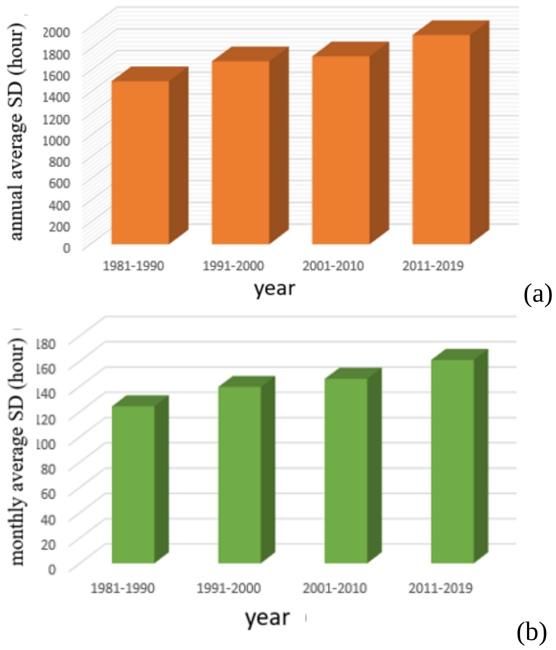


Figure 4. (a) Annual average SD and (b) monthly average of SD in Pontianak.

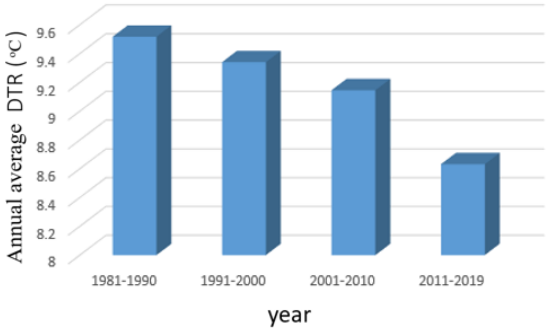


Figure 5. Annual average SD in Pontianak.

DTR distribution and changes in 1981-2019. DTR (Figure 1d) with high power occurred in the period of 8-16 months and higher periods of 32-64 months in 1985-1991 and 2000-2002. The highest DTR of the year were 11.54 ^{o}C and 11.15 ^{o}C. However, there were also DTR drops of 8.00 ^{o}C and 8.54 ^{o}C. The decrease in the DTR is associated with higher night temperatures and increased rainfall intensity.

The lowest monthly average DTR in Pontianak with 8.2oC occurred in December, while the highest monthly SD average with 9.7 ^{o}C occurred in August (Figure 2). The highest annual average DTR was found in 2013 at 7.66 ^{o}C. Meanwhile, the highest DTR occurred in 1986 at 10.48 ^{o}C (Figure 3). During the four periods analysed, there was a decrease in the DTR from the previous period. The year of 2011-2019 had the lowest DTR value with 8.65 ^{o}C whereas in 1981-1990, 1991-2000, 2001-2010, the DTR values were 9.51 ^{o}C, 9.34 ^{o}C and 9.14 ^{o}C respectively (Figure 5).

DTR as an indicator of climate change. Climate change was seen from the decrease in the DTR. We found a negative correlation between DTR and SD in Pontianak over the observed period of time (r = 0.80). Based on the DTR's sensitive nature to changes in the energy balance of radiation, DTR is an important indicator of climate change. Meanwhile, SD is one of the solar energy indicators that plays an important role in the weather or climate on Earth. Because there was an increase in the SD value, then it can be said that in 1981-2019, Pontianak was in the brigthtening period, as mentioned by other researches in the world.

Atmospheric circulation, greenhouse gases, aerosols, and land coverage /land use can also affect the DTR. For example, aerosols may have a cooling effect on T_{max} by reflecting solar radiation and affecting cloud properties. Greenhouse gases can alter surface energy and hydrological balance, thus affecting DTR. DTR is directly related to downward shortwave radiation (Rsw, d) which has different effects on T_{max} and T_{min}. The effect SD or (Rsw, d) during the day causes T_{max} (r = 0.738) to be greater than T_{min} (r = -0.109) at night. The increase in global air temperatures in the last century is largely due to increasing concentrations of greenhouse gases. Greenhouse gases can also affect T_{max} during the day and T_{min} at night.

The effect of increasing greenhouse gases and increasing (Rsw,d) results in a relatively small increase in T_{max}. Since (Rsw,d) applies only during the day, the greenhouse effect is largely responsible for the rapid increase in T_{min}. Thus, the increase (Rsw,d) results in a T_{max} smaller than T_{min} and thus the DTR becomes lower. In this way, the greenhouse effect becomes stronger, so there is a further temperature rise. Increased water vapour content can lead to increased cloud cover and can also result in changes in the amount and type of cloudiness, which modify the amount of solar energy that reaches the surface of the earth.

T_{max}, T_{min} and T_{mean} Distribution

Oscillations with periods of 8-16 months were seen in T_{max} data (Figure 1b) for 1985-1987, 1990-1993, 1998-2004, 2008-2013 and 2013-2017. Each year's T_{max} value reached 33.01^{o}C, 33.24^{o}C, 33.45^{o}C, 33.80^{o}C and 33.89^{o}C. Based on Figure 1c, CWT for T_{min} oscillations with periods of 12-20 months (centered on 16 months) was seen in 1987-1989, but also seen at higher periods of 32-64 months (centered on 48 months) in 1986-1989. T_{min} increased compared to the previous year and reached 24.48^{o}C in 1986-1989. The Increased T_{min} was also seen consistently and was also associated to the decrease in DTR.

We found that the difference between the monthly average T_{max} and the monthly average T_{min} was getting smaller. This may indicate that the monthly average T_{max} with the monthly average T_{min} does not have such a great difference. So, it is known that the monthly average T_{min} in Pontianak, West Kalimantan is getting higher and predicted to be higher.

T_{mean} had significant intermittent oscillations over a period of 8-16 months (centered on 12 months) (Figure 1e). This time series had strong annual signals in the 1982-1987, 1989-1994, 1997-1998, and 2000–2015. T_{mean} with high-power distribution indicates higher T_{mean} increases compared to years before or after. The highest T_{mean} each year reached 27.49^{o}C, 27.58^{o}C, 27.87^{o}C and 28.01^{o}C.

Average daily temperature (T_{mean}) is generally not sufficient to explain or reflect complex climate variations even though it is used as a general reference to climate change. In fact, average surface temperature trends are often caused by changes in daily maximum and minimum temperatures [26]. The rising T_{mean} is associated with the extreme increase on warm days, extreme decrease oncold days and the increase on intensity of rainfall, etc.

The high-power distribution detected indicates that at that time, the increase in T_{mean}, T_{max}, T_{min}, and the decrease in DTR were associated with the forest fires and peatland fires in Kalimantan. Indonesia's role, especially in Western Kalimantan, is crucial in suppressing global warming. That should be a common concern because West Kalimantan is the lung of the world that has a lot of forests that should be able to lower the temperature of the air that feels hotter and warmer. So, regional and global climate change has received significant attention over the last few decades. Climate change is a global phenomenon occurring worldwide. Climate change is directly or indirectly associated with human activities that change the composition of the global atmosphere such as deforestation, industrialization, and natural activity.

The Impact of Rain Patterns on the Duration of Solar Irradiation. Strong annual rainfall signals with periods of 4-8 months (centered on 6 months) were seen in 1982-1983, 1992, 1997-1998, and 2007 (Figure 1f). A strong spectrum was also shown between 2016-2017 with a period of 4-12 months. A higher period of 8-16 months (centered on 12 months) was seen in 1990-1995. In the year of El Niño, rainfall in the dry season can be less than half of the normal. This is in accordance with research conducted [27] that states that the water vapor content in the atmosphere during the dry season tends to be less, so that sunlight resistance is reduced which causes the SD value to be higher.

Pontianak belongs to the equatorial rainfall pattern type. The equatorial rainfall pattern has a bimodial monthly rain distribution with two peak rainy seasons maximum and almost all months during the year are categorized into the rainy season criteria [28]. Equatorial rainfall patterns usually occur around March and October or at the time of the equinox. Equatorial-type rainfall is also associated with The Inter-tropical Convergence Zone, or ITCZ in Pontianak, showing the highest percentages of SD in July and August, while the lowest occurred in October and December (Figure 2). It appears that, the monthly average of SD during the dry season is higher than during the rainy season.

The Impact of the 1997 El Niño on the duration of solar irradiation. E l Niño has long been associated with fire (e.g. 1972-1973, 1982-1983, 1987, 1991-1992, 1994, 1997-1998, 2002, 2006) [29]. The El Niño phenomenon has an impact on regional climate variability in the Indonesian region, especially on the variability of rainfall, i.e. low rainfall in Indonesia, resulting in drought [30]. The ENSO phenomenon is a warming period of Sea Surface Temperatures (SST) in the Eastern Pacific Equator that significantly affects the global climate. Positive SST anomalies in the region means that SST is warmer than the average climate. ENSO can be known from the Nino SST value of 3.4 and the Southern Oscillation Index (SOI) [31, 32].

El Niño also happened in 1991-1992. A decrease in 1991 rainfall was recorded in July-September (76.6 mm, 27.5 mm and 65.5 m). The data proves that there was a minimum number of rainy days and a minimum rainfall in those months. The same thing happened in 1994 in July-September with rainfall of 68.1 mm, 74.8 mm and 10.3 mm respectively. The highest rate of SD occurred in 1992 at 1,723 hours/year (compared to the previous year at only 1,400 hours/year), which also coincided with the El Niño event.

According to [27], the impact of El Niño in Indonesia can cause prolonged droughts that affect increased SD rates. The average SD in 1997 corresponding to the El Niño event was lower than El Nino in 2015/16. The decline in rainfall during the 1997/98 El Niño phenomenon was also worse than the 2015/16 El Niño [33]. However, during El Niño in 1997/98, Indonesia suffered the worst forest and land fires in the world [34]. In this study, in August-September 1997, rainfall recorded 0 mm and 55.4 mm. Despite low rainfall during the El Niño event, SD values were also low due to forest and land fire smoke (22.6 hours/month). This was reinforced by research in 1997 by [35] stating that the air temperature reached 37ºC, the humidity reached below 30% and most of the Indonesian territory's precipitation characteristics were generally below normal and there were even some areas where there was no rain at all. When the El Niño phenomenon in 1997 occurred with <50 mm rainfall within a 10-day period it caused the worst drought in Indonesia. As a result of the drought, Indonesia suffered from forest fires.

The drought in Pontianak in 1982 (at the time of El Niño) caused rainfall to crumble against normal. In July and August, rainfall deviations reached -86% and -83% respectively or 26 mm and 30.6 mm respectively. Over the past forty years, the El Niño in 1982-1983 and 1997-1998 have been the most powerful and impactful widespread. Since the outbreak of the forest fires in 1982, 1987, 1991, 1994, 1997 and the middle of 1998, it has generally occurred initially around July-November. It was then followed by rainfall of >150 mm/month until the end of 1983 (BMKG processed data).

Pontianak is in the province of West Kalimantan. West Kalimantan is one of the provinces affected by the most intense forest and land fire smoke during the 1997 El Niño. This caused the disaster of forest fires to be considered as one of the real impacts of climate change [37] and has been a major cause of deforestation in Western Kalimantan during the period of 1989-2008 [38].

In 1997, the average pH of rainwater reached 4.97, in which this pH went down compared with the one in 1996 which reached5.46. It is correlated with the dry climate conditions caused by the influence of El Niño and the terrible forest fires that have caused increased levels of pollutants both gas and dust in the atmosphere, thereby reducing the quality of rainwater. This decrease in pH occured in May, June and July with an average pH below 5.6. Pontianak was a region that at that time had a pH below 5.6 [35]. The Indian Ocean Dipole (IOD) can also affect drought in Indonesia and therefore the frequency of fires will also increase [39]. If associated with increased climate variation, this land displacement also often leads to forest fires [29]. Tropical forest fires increase the vulnerability of ecosystems to fires, leading to more frequent and severe fires from carbon absorbers to sources of carbon.

Widespread forest fires linked to the ENSO droughts in 1994, 1997 and 2002 affected cotton land in Sumatera, Kalimantan and West Papua. This caused cotton carbon reserves to decline rapidly and transfered large amounts of carbon to the atmosphere which causedsignificant implications for climate change. It is estimated that extreme seasonal precipitation associated with ENSO events in the future tends to become clearerand may lead to reduced water supply and increased likelihood of peatland fires.

In addition to the rainfall deficit, in October 1991-April 1992 and 1995, it was detected that the rainfall level was >150 mm/month. The year of 2007 also experienced precipitation of >150 mm/month, except in February (91.7 mm) and August (124.6 mm). Increased rainfall intensity (although with some regional variation) in the future climate towards an increase in greenhouse gases is one of the early models of extreme rainfall.

In addition to the annual period, the half-year renewal period associated with the ITCZ is also visible. ITCZ is an area with a very high potential for active rain clouds growth, so the likelihood of precipitation is very high. When ITCZ passes through Indonesia, the probability of causing rainfall in those months becomes high. So it becomes logical when the semi-annual frequency (periodicity 6 months) and the annual frequency (12 months) show high values. However, this could be disturbed by the occurrence of the El Niño phenomenon and possible anomalies related to the sea level in the tropical Atlantic Ocean. In this year of El Niño, it can cause a significant reduction in rainfall.

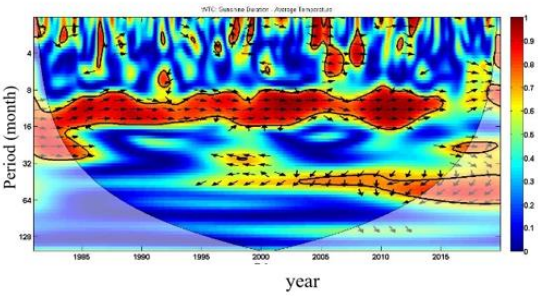
Wavelet Coherence analysis (WTC). This section discusses information about phase differences when using complex wavelet functions. Phase differences can be calculated by using the imaginary and real parts of the Cross Wavelet Transform (XWT) separately or better known as the Wavlet Coherence (WTC) which can determine significant coherence between two-time series [40]. In the plot wavelet coherence, strong correlations with values close to 1 are marked with a red colour while low or non-correlation with a value close to 0 is shown by the blue colour in the figure.

The wavelet coherence plot comes with a phase difference. The phase difference is indicated by the arrow on a significant area in the wavelet coherence plot. The right arrow in a time series describes a positive correlation where both time series move in the same phase, whereas the left arrow indicates the times series moving in the opposite phase (negative correlation). The up arrow means the first time series precedes the second time series in positive correlation (phase) and the latter time series precedes the first line in negative (opposite phase). Instead, the down arrow indicates the second time series precedes the first-time line in positive correlation (phase) and the first time series precedes the second time series in negative correlations (opposite phase).

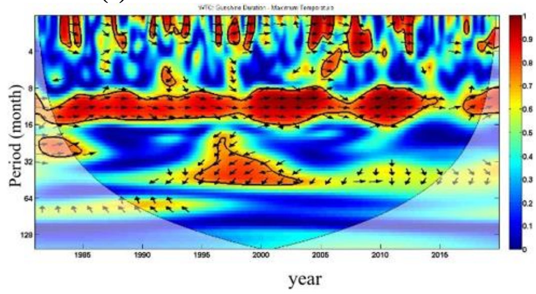
Based on the plot wavelet coherence (Figure 6a-b), it is seen that the SD time series has a correlation with T_{mean} and T_{max} shown with values close to 1 or marked with red power. SD, T_{mean} and T_{max} generally moved in the same phase. The greatest concentration was in the period of 8-16 months (centered on 12 months) that shows this time series had strong annual signals in 1982-2015.

SD changes have a significant impact on T_{mean} and T_{max} or, in other words, T_{max} is sensitive to SD change [41]. Then, the two-time series moved in opposite phases where the arrow down to the left with the first time series (SD) precedes the second time series of time (T_{max}) in a higher period (24-48 months) in 1994-2001 (Figure 6b). There is a strong positive linear correlation between SD, T_{mean} and T_{max} (marked with r = 0.76 and r = 0.74). Based on research [42] reports that there has been a decadent change in SSR observed since the second half of the 20th century. SSR variations have the potential to significantly affect the climate system [43], changes in temperature on the Earth's surface [44] and hydrological cycles.

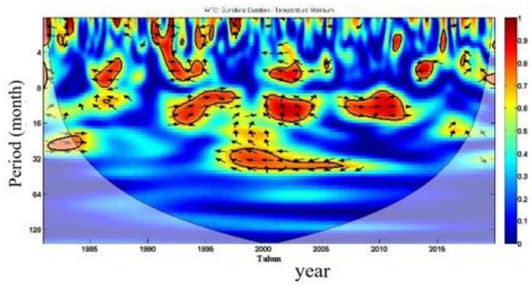
SD and T_{min} (Figure 6c) are in the same phase as the SD time series preceding T_{min} in the 8–16-month period (centered on 12 months) in 1992-1996 and 2007-2011. However, it was also found that both time series moved in opposite phases with the upper left arrow in the period of 8-16 months in 2000-2004 and the higher period of 24-48 months in 1997-2005 as a negative correlation because T_{min} is usually a night temperature that is slightly affected by solar radiation.



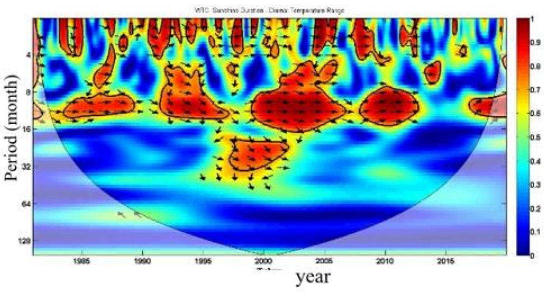
(a) *Wavelet coherence* SD and T_{mean}



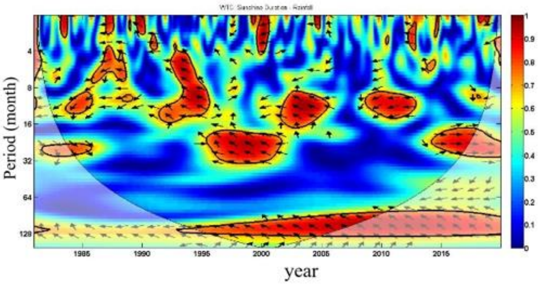
(b) *Wavelet coherence* SD and T_{max}



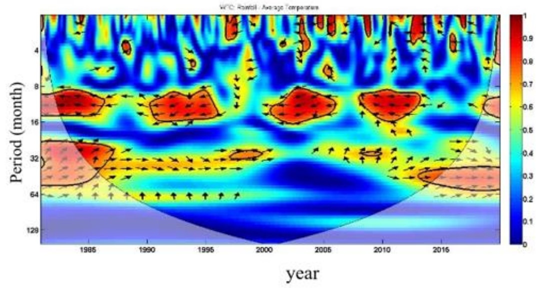
(c) *Wavelet coherence* SD and T_{min}



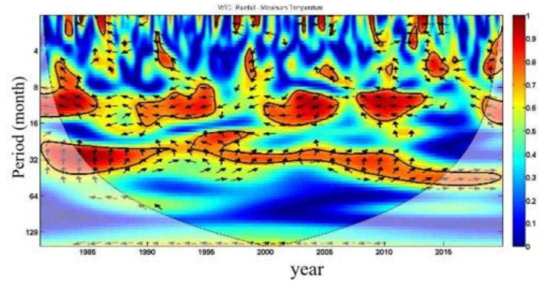
(d) *Wavelet coherence* SD and DTR



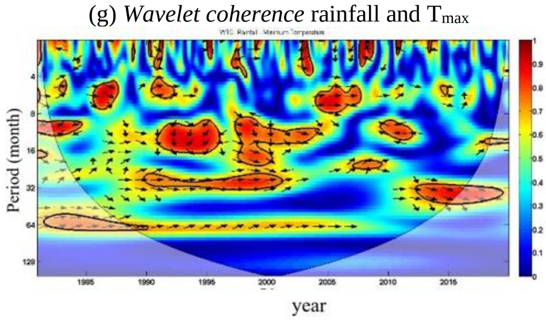
(e) *Wavelet coherence* SD and rainfall



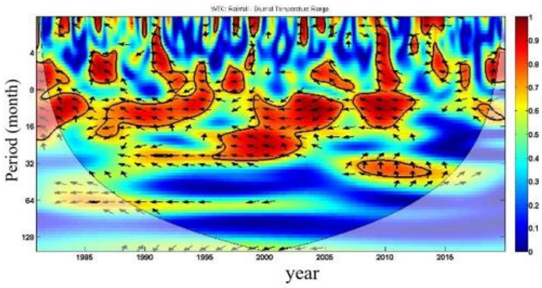
(f) *Wavelet coherence* rainfall andT_{mean}



(g) *Wavelet coherence* rainfall and T_{max}



(h) *Wavelet coherence* rainfall and T_{min}



(i) *Wavelet coherence* rainfall and DTR

Figure 6. Wavelet coherence in Pontianak, West Kalimantan. Color codes for power range from blue (low power) to red (high power). The Y-axis measures the period and the X-axis represents the observed time series (1981-2019).

Then, SD and DTR (Figure 6d) moved in the same phase indicated by the right bottom right arrow in the period of 6-16 months in 1983-1988, 1991-1996, 1999-2006 and 2008-2012. It was also found to have a higher period of 16-48 months in 1997-2001 with the DTR time series preceding the SD time series. Overall, the results shown describe SD and DTR as negative correlations.

The plot of the WTC between SD and precipitation (Figure 6e), rainfall and T_{mean} (Figure 6f), rainfall and T_{max} (Figure 6g), rainfall and DTR (Figure 6i), are in opposite phases that assumes a weak correlation between the parameters. It was also reported by the IPCC that the decrease in the DTR is associated with higher night temperatures and increased precipitation intensity resulting in a negative correlation between precipitation and DTR. Cloud cover and precipitation have significant effects on the surface's energy and hydrological balance and are therefore widely identified as the leading causes of DTR reduction. Clouds can reduce T_{max} by reducing shortwave radiation that comes to the Earth's surface during the day and increase T_{min} by blocking longwave radiation coming out at night, thereby negatively affecting the DTR [45]. In other words, rainfall can reduce T_{max} and DTR through evaporative cooling.

SD and rainfall are in opposite phases (negative correlation) where the rainfall time series precedes the SD time series (Figure 6e). The negative linear correlation between SD and precipitation is r = -0.69. The opposite phase is indicated by the upper-left arrow with a low period of 4-16 months in 1991-1995. It was also seen with a higher period of 8-16 months in 2001-2005 and a period of 16-32 months in 1995-2001. The SD time series precedes the rainfall time series indicated by the bottom-left arrow with a period of 8-16 months in 2008-2012.

Plot of the WTC between rainfall and T_{mean} (Figure 6f) with a period of 8-16 months (centered on 12 months) with arrows to the top left in 1982-1985 and 2008-2012 while arrows down left in 1990-1995 and 2000-2005. Besides, it was also seen in a higher period of 24-48 months with two observation areas moving in the same phase marked by the upper right arrow that occurred in the years of 1984-1986 and 2007-2012. In general, the results shown describe rainfall and T_{mean} as a negative correlation r = -0.48. Next, the T_{max} time series precedes the rainfall time series in negative correlation (Figure 6g). Rainfall and T_{max} are at the opposite phases that the arrow indicates to the top left and the bottom left. The period of 6-16 months occurred in 1983-1985 and 2007-2012. Besides, in a period of 8-16 months with a bottom-left arrow occured in 1989-1995 and 2000-2005 (the rainfall time series precedes the T_{max} time series). These two-time series were also found to move in the same phases indicated by the upper-right arrow in a period of 16-48 months with longer time occurring in the years of 1984-1991 and 1993-2012.

Observation of the rainfall time series and T_{min} (Figure 6h) moved with the same phase (positive correlation) marked by the bottom right arrow with a period of 4-8 months in 1986-1987, then, with a higher period of 8-16 months in 1997-2004. These two-time series also moved together in 2004-2007 and 1990-2000 with periods of 4-8 months and 24-32 months respectively. The opposite phase of the rainfall time series preceding the T_{min} time series was seen at a frequency of 8-16 months in 1990-1995. Furthermore, the wavelet coherence that occured at rainfall and DTR (Figure 6i) moved in opposite phases on almost all scales and times marked with arrows to the left (negative correlation with r = -0.84). The DTR time series precedes the rainfall time series with periods of 4-6 months in 1985-1987, 1996-1997, 2004-2006 and 2014 and next, with a period of 2-16 months in 1982-1984, 1986-1995, and 2007-2012. It was also seen in 1995-2005 and 2007-2012 with higher periods of 8-32 months and 32-48 months, respectively.

4. Conclusion

Climate change has been seen from the decrease in DTR. Based on this research, negative correlation was found between DTR and SD in Pontianak over the observed period of time (r = -0.80). DTR are sensitive to changes in the energy balance of radiation so DTR is an important indicator of climate change. SD becomes an indicator of solar energy that plays an important role in weather or climate on earth. Due to the increase in SD value in 1981-2019, it can be said that Pontianak, Indonesia was in a period of brightening caused by changes in the characteristics of clouds and aerosols leading to an increase in the amount of solar energy reaching the surface of the earth. Intermittent oscillations SD dominates 8-16 months (centered in 12 months) while DTR has a dominant period of 8-16 and 32-64 months. SD changes have a significant impact on T_{mean}, T_{max} and T_{min} because they are sensitive to temperature changes in SD. A faster increase in T_{min} than T_{max} causes a decrease in DTR.

Analysis of wavelet using CWT and WTC in the time series in Pontianak is able to show an important part of the recent global warming (1981-present). The T_{max} and T_{mean} time series have strong annual signals. T_{max} oscillation, with a period of 8-16 months (centered on 12 months) was seen in 1985-1987, 1990-1993, 1998-2004, 2008-2013 and 2013-2017. T_{min} with a period of 12-20 months (centered on 16 months) was seen in 1987-1989. T_{mean} was significant over a period 8-16 month (centered on 12 months). This time series has strong annual signals of 1982-1987, 1989-1994, 1997-1998, and 2000-2015.

The difference between the monthly average T_{max} and the monthly average T_{min} is getting smaller. This may indicate that the monthly average T_{max} with the monthly average T_{min} does not have such a distant difference. So, it is known that the monthly average hour in Pontianak, West Kalimantan is getting higher and predicted to be higher.

The rainfall during El Niño in August-September recorded at 0 mm and 55.4 mm. Although rainfall was low during El Niño events, the SD values were also low due to coverage forest and land fire smoke cover (22.6 hours/month). Widespread forest fires associated with the ENSO droughts in 1994, 1997 and 2002 affected peatlands, resulting in rapidly decreasing crab carbon reserves and transferring large amounts of carbon to the atmosphere. These events have significant implications for climate change.

Suggestion

Changes in SD to other climatological parameters will be visible if there is data of period dimming and brightening of a region or the years of 1950-1980 and 1981-2019. Since there is still a minimum of research on this, it is suggested that this research can be continued in each region so that the impact of climate change and global warming in Indonesia will be seen.

References

[1] Tonkaz, T dan Ocak, S. 2017. Long-Term Trends of Sunshine Durations in Relation with Cloudiness and Relative Humidity in GAP Area, Turkey, Journal of International Environmental Application and Science, Vol. 12, no. 2 pp 147– 53.

[2] World Meteorological Organization (WMO). 2008. *Guide to Meteorological Instruments and Methods of Observation*, Part-1, Ch.8. Measurement of the sunshine duration, 7th ed, Geneve, Switzerland.

[3] Babu Ram Tiwari, et al, "Wavelet and cross correlation analysis on some climatology parameters of Nepal", *BIBECHANA*, vol. 18, no 2, pp. 105-116, 2021

[4] H. J. Li, J. E. Gao, H. C. Zhang, Y. X. Zhang, and Y.Y. Zhang, "Response of Extreme Precipitation to Solar Activity and El Nino Events in Typical Regions of the Loess Plateau Hindawi", *Advances in Meteorology*, 2017.

[5] Yang, J., Liu, H.-Z., Ou, C.-Q., Lin, G.-Z., Zhou, Q., Shen, G.-C, Guo, Y. (2013). *Global climate change: Impact of diurnal temperature range on mortality in Guangzhou, China. Environmental Pollution, 175, 131–136.* doi:10.1016/j.envpol.2012.12.021

[6] Li, W., Hou, M., Xin, J, "Low-cloud and sunshine duration in the low-latitude belt of South China for the period 1961–2005", *Theor. Appl. Climatol*, Vol 104, pp 473–478, 2011.

[7] Matuszko, D, "Long-term variability in solar radiation in Krakow based on measurements of sunshine duration". *Int. J. Climatol*, Vol 34, pp 228–234, 2014.

[8] Lindvall, J. & Svensson, G, "The diurnal temperature range in the CMIP5 models". *Clim. Dyn*. Vol 44, pp 1–17, 2014.

[9] Sun, D., Pinker, R. T., & Kafatos, M. (2006). Diurnal temperature range over the United States: A satellite view. *Geophysical research letters*, *33*(5).

[10] Karl, T. R., Knight, R. W., Gallo, K. P., Peterson, T. C., Jones, P. D., Kukla, G., ... & Charlson, R. J. (1993). A new perspective on recent global warming: asymmetric trends of daily maximum and minimum temperature. *Bulletin of the American Meteorological Society*, *74*(6), 1007-1023.

[11] Braganza, K., Karoly, D. J., & Arblaster, J. M. (2004). *Diurnal temperature range as an index of global climate change during the twentieth century. Geophysical Research Letters, 31(13), n/a–n/a.* doi:10.1029/2004gl019998

[12] Shen, X., B. Liu, G. Li, Z. Wu, Y. Jin, P. Yu, and D. Zhou, "Spatiotemporal change of diurnal temperature range and its relationship with sunshine duration and precipitation in China", *J. Geophys. Res. Atmos*., Vol. 119, pp. 13.163–13.179, 2014.

[13] Matuszko D and Stanisław Weglarczyk, "Relationship between sunshine duration and air temperature and contemporary global warming", *International Journal of Climatology Int. J. Climatol*, vol. 35, pp. 3640–3653, 2015.

[14] E. O. Falayi, A. T. Adewole, A. D. Adelaja, T. O. Roy-Layinde, "Wavelet spectrum analysis of Air temperature and Relative humidity in some selected stations in Nigeria", *Dutse Journal of Pure and Applied Sciences*, vol. 6, no. 1, pp. 47-59, 2020.

[15] Badan Lingkungan Hidup (BLH), 2010, Iklim Pontianak. (http://blh.pontianakkota.go.id/indek.p hp/main=statistik&sub=iklim).

[16] Islammiyati, dkk, "Analisis Potensi Energi Matahari Menggunakan Data Lama Penyinaran Matahari (LPM) Kota Pontianak**"**, *Prisma Fisika*, Vol.7, No.3, 2019.

[17] Yuggotomo, dkk, "Perubahan Lama Penyinaran Matahari Tahun 1990-2019 Di Kalimantan Barat", *Jurnal Meteorologi Klimatologi dan Geofisika* Vol.7 No.3, pp 58-65, November 2020.

[18] E.O. Falayi, J.O. Adepitan, O.S. Ojoniyi, A.A . Okusanya, K.A. Egunjobi and F.O. Ogunsanwoo, “Analysis of rainfall and maximum temperature using wavelet transformation”, *J. NAMP*, Vol. 42, pp. 427-436, 2017.

[19] Santos, C. A., Silva, R. M., & Akrami, S. A, “Rainfall analysis in Klang River Basin using continuous wavelet transform. *Journal of Urban and Environmental Engineering*", vol. 10, no. 1, pp. 3-10, 2016.

[20] Sang, Y. F, “A practical guide to discrete wavelet decomposition of hydrologic time series”. *Water resources management*, vol. 26, no. 11, pp. 3345-3365, 2012.

[21] Aguiar-Conraria, L. dan Soares, M.J, “The Continuous Wavelet Transform” A Primer. NIPE *Working Papers* 16/2011, Universidade do Minho, 2011.

[22] J. O. Adepitan and E.O. Falayi, “Variability changesof some climatology parameters of Nigeria using wavelet analysis” *Scientific African* e00017, vol.2, pp 1-11, 2019.

[23] Iswati, S., Atmojo, S. W., dan Budiastuti, S, “Kajian Perubahan Pola Tutupan Lahan Gambut Terhadap Anomali Iklim Di Wilayah Kabupaten Kubu Raya Propinsi Kalimantan Barat”, *Jurnal Ekosains*, Vol. V, no. 2 pp 40–46, 2013

[24] Liepert, B.G, “Observed reductions of surface solar radiation at sites in the United States and worldwide from 1961 to 1990”, *Geophys. Res. Lett*, vol. 29, no.10, pp. 1421, 2002.

[25] Norris, J. R., & Wild, M, “Trends in aerosol radiative effects over Europe inferred from observed cloud cover, solar “dimming,” and solar “brightening”. *Journal of Geophysical Research: Atmospheres*, 112(D8), 2007.

[26] Agidi, VA; Hassan, SM; Baleri, TJ, “Diurnal Temperature Range as Index of Climate Change in Lafia, Nasarawa State, Nigeria”, *J. Appl. Sci. Environ. Manage*. Vol. 26 (2) 233-236 February 2022

[27] Hamdi, S. dan Sumaryati, “Pola Lama Penyinaran Matahari Dalam 20 Tahun Pengamatan Di Sumedang”, *Jurnal Sains Dirgantara*, Vol. 17, no. 2 pp 81–94, 2020.

[28] Nelvi, Afni, dkk, “Analisis Curah Hujan Harian Untuk Menentukan Pola Terjadinya Fenomena Madden Julian Oscillation (MJO) Di Daerah Sekitar Ekuator Indonesia”, *Pillar of Physics*, vol.4, pp 57-64, 2014.

[29] Cochrane M A, Alencar A, Schulze M D, Souza C M Jr, Nepstad D, Lefebvre P and Davidson E A, “Positive feedbacks in the fire dynamics of closed canopy tropical forests”, *Science* 284, pp. 1832-1935, 1999.

[30] Aldrian, E & Susanto, R.D., “Identification of Three dominant Rainfall Regions Within Indonesia and their Relationship to Sea Surface Temperature”. *International Journal of Climatology*, vol. 23, pp.1435-1452, 2003.

[31] Nelvi, Afni dan Wahyu Srigutomo, “Analisis Dinamika Atmosfer Dan Lautan Bulan Januari - Februari 2016 Di Padang”, *Prosiding SNSA*, hal 11-19, 2016.

[32] Hidayat Anistia Malinda dkk, “Korelasi Indeks Nino 3.4 Dan Southern Oscillation Index (SOI) Dengan Variasi Curah Hujan di Semarang”, *Jurnal Sains & Teknologi Modifikasi Cuaca*, Vol.19 No.2, pp 75 – 81, 2018.

[33] Yuda, I W. A., Prasetia, R., Nursa’idah, dan Wiratmaja, M. D, “Perbandingan Dampak El Nino Kuat 2015/16 dan 1997/98 Terhadap Curah Hujan Di Provinsi Bali –Indonesia, *Megasains*, Vol. 11, no. 2 pp 28–35, 2020.

[34] Tacconi, L, “Fires in Indonesia: Causes, Costs and Policy Implications”, *CIFOR Occasional Paper* no.24, Center for International Forestry Research, Bogor, 2003.

[35] Zakir, A., Sulistya, W., Swarinoto, Y.S., and P.A., Winarso, The extreme weather condition during the period of forest fire event 1997 in Indonesia. Paper was presented in training couse on the health guidelines on forest fire episodic events, Kualalumpur, Malaysia, 1998.

[36] Barber, C.V. dan Schweithelm, J, “Trial by Fire: Forest Fires and Forestry Policy in Indonesia’s Era of Crisis and Reform”, World Resources Institute, Washington DC, 2020.

[37] Anggraini, N. dan Trisakti, B, “Kajian Dampak Perubahan Iklim Terhadap Kebakaran Hutan Dan Deforestasi di Provinsi Kalimantan Barat”, *Jurnal Penginderaan Jauh*, Vol. 8, pp 11–20, 2011.

[38] Carlson, K. M., Curran, L. M., Ratnasari, D., Pittman, A. M., Soares-Filho, B. S., Asner, G. P., Trigg, S. N., Gaveau, D. A., Lawrence, D., dan Rodrigues, H. O. (eds). “Committed Carbon Emissions, Deforestation, and Community Land Convertion from Oil Palm Plantation Expansion in West Kalimantan, Indonesia”, *Proceedings of the National Academy of Sciences*, 7559–64, 2012.

[39] Field, R. D., Van Der Werf, G. R., & Shen, S. S, “Human amplification of drought-induced biomass burning in Indonesia since 1960”, *Nature Geoscience*, 2(3), 185, 2009.

[40] Grinsted, A., Moore, J. C., & Jevrejeva, S, “Application of the cross wavelet transform and wavelet coherence to geophysical time series”. *Nonlinear processes in geophysics*, 11(5/6), pp. 561-566, 2004.

[41] Purwanto, dkk, Pembangunan berkelanjutan: Tinjauan beberapa pilar, Pontianak, PT. Putra Pabayo Perkasa, 2023, p.119.
[42] Hartmann, D. L., Tank, A. M. K., Rusticucci, M., Alexander, L. V., Brönnimann, S., Charabi, Y. A. R., and Soden, B. J, "Observations: atmosphere and surface. In Climate Change 2013 the Physical Science Basis: Working Group I Contribution to the Fifth Assessment *Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, 2013.
[43] Wild, M, "Global dimming and brightening: A review", *Journalof Geophysical Research: Atmospheres*, 114(D10), 2009.
[44] Wild, M, "Enlightening global dimming and brightening", *Bulletin of the American Meteorological Society*, *93*(1), pp. 27-37, 2012.
[45] Xia, X, "Variability and trend of diurnal temperature range in China and their relationship to total cloud cover and sunshine duration". In *Annales Geophysicae*, vol. 31, no. 5, pp. 795-804, 2013.