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THE INFLUENCE OF EL NINO AND LA NINA ON BIAK RAINFALL IN 30 YEARS (1981-2010) Prayoga Ismail* and Aries Kristianto 1Indonesian State College of Meteorology Climatology and Geophysics (STMKG), Jalan Perhubungan I No.5 Komplek Meteorologi Pondok Betung, Bintaro 15221, Indonesia *Corresponding author: yogamailforalvin@gmail.com Abstract Research on the influence of El Nino and La Nina during 30 years is focused in Biak. Rainfall data (1981-2010) is based on Biak Meteorological Station observation. ENSO activities and its teleconnection to the variability of monthly rainfall has been evaluated by analyzing the response of the monthly rainfall and ENSO-related activities through the comparison of normal monthly rainfall and ENSO events composites. During El Nino, Biak monthly rainfall tends to decrease until it reached 42.55% which took place in October. While, La Nina tended to leave positive impact on Biak monthly rainfall of up to 54.27%, which occurred in September. The influence of El Nino and La Nina most to the seasonal rainfall occurred in the SON as a transition period from dry to rainy season. Correlation analysis between Biak monthly rainfall and Nino 3.4 index during the period revealed that ENSO activities gave a negative impact on Biak monthly rainfall with the highest correlation coefficient occurred in October, reaching -0.55. This number indicated a moderate correlation Keywords: Biak rainfall, el nino, la nina Introduction ENSO (El Nino and Southern Oscillation) phenomenon is anomalous increase or decrease in sea surface temperature (SST) of the normal value which occurs in the central and eastern region of equatorial Pacific Ocean (Philander, 1990). This global impact tropical circulation is divided into two phases: El Nino (warm phase) and La Nina (cold phase). There are many previous studies that proved that the activities of ENSO influenced on rainfall variability in the region of Indonesia (Gutman et al., 2000; Aldrian, 2002; Mulyana, 2002; Hamada et al., 2002; Hendon, 2003). Meanwhile, the influence of ENSO activities to rainfall in eastern Indonesia (Papua) have also been studied previously (Kubota et al., 2011; Suwandi et al., 2014). From various studies the influence of ENSO activities on rainfall over Indonesia had been known clearly. However, need more studies to determine the influence of ENSO activities on rainfall for a smaller scope area to understand better. In this case, the research conducted on Biak region, which is a municipal level (district). This paper is a review of the influence of ENSO activities on Biak monthly rainfall over a period of 30 years (1981-2010) and to find out the relationship between Nino 3.4 index and Biak monthly rainfall during this period. This study is expected not only to support and complement previous studies but also to provide a more comprehensive understanding related to the influence of ENSO activities in Biak monthly rainfall over a period of 30 years. Biak is one of the districts in the province of Papua, Indonesia. Based on the monthly rainfall data over a period of 30 years (1981-2010), Biak classified as equatorial type, one of the three existing rainfall patterns in Indonesia (Rouw et al., 2014). Aldrian and Susanto (2003) explained that the different response types of rain with SST in Indonesia, so the differential responses will appear when ENSO events. In the east, Biak, which is located directly adjacent to the western equatorial Pacific Ocean is certainly closer to the ENSO phenomenon compared to other regions of Indonesia. This fact is at once interesting to be elaborated how the influence of ENSO activities during the period 1981- 2010 to the monthly rainfall specifically in Biak district. Then, the teleconnections to climate change The 6th International Symposium for Sustainable Humanosphere Humanosphere Science School 2016 Bogor, 15 – 16 November 2016 75 impacts on the environment can be known. The research will also gives benefit for BMKG (Indonesian Agency for Meteorology Climatology and Geophysics), governments and communities to provide knowledge related to El Nino and La Nina events so it can be used for mitigation in the upcoming events. Materials and Methods This study used monthly rainfall data over a period of 30 years (1981-2010), which collected from the observation data of Frans Kaisiepo Biak Meteorological Station. The data is classified as secondary data because the precipitation observations is done directly by the observer using obs rain gauge which is managed and stored properly and quite representative for Biak district, especially the airport area. The data also being a dependent variable in this study. Monthly rainfall data over a period of proficiency level will be computed into the value of the average monthly rainfall consist of 12 normal rainfall data from January to December. Then, it will be graphed to determine the pattern of Biak monthly rainfall. Calculations were performed by using the following equation: 1 n X n xi1 Xi (1) As stated in Pratama, 2013. In formula (1), X is average monthly rainfall for the period of 1981-2010 (mm units), n is the number of monthly rainfall data over a period of 30 years, and Xi is the value of the monthly rainfall (mm units). Then, the data used to identify the time of occurrence of ENSO is monthly SST anomaly Nino 3.4 index data during the period 1981 to 2010 as shown in chart 1 which includes the equatorial Pacific Ocean region with astronomical area 50 S - 50 N and 1200 W - 1700 W. The data were taken from NOAA ESRL Physical Science Division with HadISST dataset with the provision, El Nino event occurs when an index number-value ≥ 0.5. Whereas, for the event La Nina occurs when the index number is worth ≤ -0.5. Nino 3.4 index as well as the independent variable in this study. After determining the time of ENSO events in the phase of El Nino and La Nina, each data will be calculated into the composite average monthly rainfall data when the activities of the El Nino and La Nina occurs. The rainfall composites occurrence of El Nino and La Nina yield 12 monthly rainfall data from January to December. After that, it will be graphed to determine the pattern of Biak monthly rainfall upon occurrence of El Nino and La Nina. Calculations were performed using the following equation: 1 n (2) X = n xå Xi i=1 As stated in Pratama, 2013. In formula (2), X is the average monthly rainfall El Nino or La Nina filter during the period 1981-2010 (mm), n is the number of monthly rainfall data El Nino or La Nina filter for the period of 30 years, and Xi is the value of the monthly rainfall El Nino or La Nina filter (mm). In this study, the methods are response analysis and correlation analysis using Pearson correlation coefficient. Analysis of Biak monthly rainfall response to ENSO events will be assessed through rainfall anomaly that occurs when the El Nino and La Nina events. ENSO events rainfall composite in the phase of El Nino and La Nina during the period 1981 to 2010 will be calculated into the average monthly and compared with the Biak monthly rainfall in a normal period (1981-2010). Then, it will be seen how the influence of the El Nino and La Nina activities on rainfall composite for each months. Methods of correlation analysis is using Pearson correlation coefficient intends to explore the extent of the closeness of the linear relationship between variability of Biak monthly precipitation and Nino 3.4 SST anomaly index over a period of 30 years (1981-2010), by using the following equation: r n XY X Y n X X n Y Y2 2 2 2 ( ) ( ) (3) As stated in Pratama, 2013. In formula (3), r is the Pearson correlation coefficient, n is the number of Nino 3.4 index data over a period of 30 years, X is the value of Biak monthly rainfall during the period from 1981 to 2010 (mm), and Y is Nino 3.4 SST anomaly the index value (0C) during the period. Meanwhile, SST anomalies composite map was processed by using the Research and Development Application of NOAA's Earth System Research Laboratory, Physical Science Division. Results and Discussion Biak rainfall pattern Indonesia is divided into three predominant regions of the rainfall patterns (Aldrian & Susanto, 2003). Based on rainfall patterns during a period of 30 years as shown in the Figure 1 (a), Biak which is located in eastern Indonesia became one of the areas in Papua, can be categorized as the equatorial rainfall pattern. The pattern is seen from the graph that resembles with two peaks period that occurred in March and July. In general, Biak monthly rainfall interval is under 100 mm. Biak which is located to the west of the equatorial Pacific Ocean, so the weather and climate oscillations that occur in the Pacific it is possible to give impact to the variability of the weather and climate in the region. Response analysis Based on Figure 1 (b), showed that Biak monthly rainfall pattern changes when there is activities of El Nino (yellow line) and La Nina (blue line). In general, the activities of the El Nino tends to cause a reduction in the monthly rainfall in Biak. Meanwhile, the activities of La Nina tends to cause Biak monthly rainfall increase. These are the dominant results. Reduction of rainfall means that the monthly precipitation is below normal, while the increasing of rainfall means that the monthly rainfall is above normal. Nevertheless, from the response analysis there are cases which experienced the opposite, namely the addition of monthly rainfall when El Nino activities, and a decrease in the monthly rainfall when La Nina activities. However, the cases were minimal and not dominant. a. b. 350.0 350.0 300.0 300.0 250.0 (mm)250.0 (mm) 200.0 200.0 150.0 150.0 100.0 100.0 RAINFALL RAINFALL 50.0 50.0 0.0 0.0 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 MONTH MONTH 30 YEARS MEAN El Niño MEAN 30 YEARS MEAN La Niña MEAN Figure 1. (a) Biak monthly rainfall pattern over a period of 30 years (1981-2010); (b) Biak monthly rainfall pattern of normal value, El Nino filter (yellow), and La Nina filter (blue) for same period Monthly rainfall response As shown in Figure 2, based on response analysis composite between normal monthly rainfall from January to December 1981-2010 and monthly rainfall during ENSO activities during the same period, showed that monthly rainfall anomalies in ENSO activities. In January, the activities of the El Nino and La Nina were both a positive influence in the form of increased rainfall in Biak, respectively of 5.15% (13.3 mm) and 2.43% (6.3 mm) to normal. In February, El Nino activities caused a decrease in the monthly rainfall amounted to 2.43% (6.3 mm), while the activities of La Nina impact was quite clear in the form of increased rainfall of up to 24.74% (58 mm) to normal. In March, El Nino activities had little impact on reducing monthly rainfall amounting to 1.15% (3.3 mm), and the activities of La Nina impact on increasing the monthly rainfall amounted to 9.56% (27.4 mm) to normal. In April, the activities of the El Nino and La Nina nearly had the same impact that increase Biak monthly rainfall respectively by 11.51% (30.2 mm) and 10.27% (27 mm) to normal. In May, the influence of El Nino activities impact on the monthly rainfall decrease amounted to 20.29% (47 mm), while the activities of La Nina impact on increasing the monthly rainfall of up to 33.83% (78.3 mm) to normal. In June, El Nino activities also decreased the monthly rainfall amounted to 13.02% (28.8 mm), whereas La Nina activities increase monthly rainfall amounted to 5.36% (11.9 mm) to normal. Unique cases also occurred in July, where the second phase of ENSO (El Nino and La Nina) caused a decrease in monthly rainfall, respectively amounting to 19.58% (53.6 mm) occurred when the activities of El Nino, and 15.71% (43 mm) occurred when La Nina activities. In August, the influence of El Nino caused a decrease in the monthly rainfall amounted to 25.34% (58.7 mm), and the influence of La Nina activities led to an increase in the monthly rainfall amounted to 26.82% (62.1 mm) to normal. In September, the activities of the El Nino caused a decrease in the monthly rainfall amounted to 21.45% (45.6 mm), whereas La Nina activities provided significant influence in the form of an increase of monthly rainfall reached 54.27% (115.4 mm) in which La Nina impact this month was the biggest among other months. In October, El Nino activities caused the highest decrease in the monthly rainfall compared to other months, reaching 42.55% (95.4 mm), whereas La Nina activities impact on the addition of monthly rainfall amounted to 19.05% (42.7 mm). In the earlier of November, the two phases of ENSO again having the same impact, a reduction in monthly rainfall, respectively amounting to 13.89% (26.7 mm) when the activities of El Nino and 6.27% (12.1 mm) when the activities of La Nina. In December, El Nino activities had a negative impact in the form of a decrease in the monthly rainfall amounted to 11.41% (29.1 mm), whereas La

Nina activities provided little positive impact as addition of monthly rainfall only 1.79% (4, 6 mm) to normal. 60.00% 40.00% 20.00% 0.00% 1 2 3 4 5 6 7 8 9 10 11 12 -20.00% -40.00% -60.00% MONTH El Niño ANOMALY La Niña ANOMALY Figure 2. Percentage of monthly rainfall anomalies in Biak period of 30 years for El Nino filter (yellow), and La Nina filter (blue) Seasonal rainfall response Based on Figure 3, DJF (December, January,and February) represented the rainy season in Indonesia. In this period, DJF normal rainfall in Biak experienced a slight decrease of 2.07% (15.8 mm) when the El Nino activities. Meanwhile, the activities of La Nina, DJF normal rainfall increased slightly in the amount of 1.94% (14.8 mm). From these results, it appeared that in the rainy season, the activities of the El Nino and La Nina gave a little impact with almost similar anomalies on Biak rainfall. a. b. DJF DJF Anomaly 790.0 780.0 LA NINA 770.0 760.0 750.0 740.0 EL NINO 730.0 EL NINO NORMAL LA NINA -3.00% -2.00% -1.00% 0.00% 1.00% 2.00% 3.00% Figure 3. (a) Response and (b) anomalies of Biak rainfall in DJF when the activities of El Nino and La Nina in 30 years period Based on Figure 4, MAM (March, April, and May) represented the transition season or period from the rainy season to the dry season in Indonesia. In this period, a normal rainfall MAM decreased slightly by 1.62% (12.6 mm) when the El Nino activities. Meanwhile, when the activities of La Nina, normal rainfall MAM increased more in the amount of 14.44% (112.8 mm). This result showed that in the MAM transition season, the influence of La Nina activities was stronger than El Nino impact on Biak rainfall. a. b. MAM MAM Anomaly 950.0 LA NINA 900.0 850.0 800.0 750.0 EL NINO 700.0 EL NINO NORMAL LA NINA -5.00% 0.00% 5.00% 10.00% 15.00% 20.00% Figure 4. (a) Response and (b) anomalies of Biak rainfall in MAM when the activities of El Nino and La Nina in 30 years period The 6th International Symposium for Sustainable Humanosphere Humanosphere Science School 2016 Bogor, 15 – 16 November 2016 79 a. b. JJA JJA Anomaly 800.0 600.0 LA NINA 400.0 200.0 EL NINO 0.0 EL NINO NORMAL LA NINA -30.00% -20.00% -10.00% 0.00% 10.00% Figure 5. (a) Response and (b) anomalies of Biak rainfall in JJA when the activities of El Nino and La Nina in 30 years period Based on Figure 5, JJA (June, July, and August) represented the dry season in Indonesia. In this period, a normal JJA Biak rainfall quite real decline in the amount of 22.65% (164.5 mm) on the activities of El Nino. However, on the activities of La Nina, normal JJA rainfall only increased slightly amounting to 1.84% (13.4 mm). It can be seen that in JJA (dry season), the impact of El Nino on Biak rainfall was stronger than the influence of La Nina. a. b. SON SON Anomaly 1000.0 800.0 LA NINA 600.0 400.0 200.0 EL NINO 0.0 EL NINO NORMAL LA NINA -40.00% -20.00% 0.00% 20.00% 40.00% Figure 6. (a) Response and (b) anomalies of Biak rainfall in SON when the activities of El Nino and La Nina in 30 years period Based on Figure 6, SON (September, October, and November) represented the transition season, from dry season to the rainy season in Indonesia. At the time, a normal SON Biak rainfall decreased greater than most other seasons, reaching 27.08% (170.4 mm) when the El Nino activities. Meanwhile, when the activities of La Nina, normal SON rainfall also increased greater than most other seasons, reaching 32.91% (207 mm). It showed that in the SON transition season, the influence of El Nino and La Nina activities provided the most significant influence on Biak rainfall compared to the other seasons. Correlation analysis By using the Pearson correlation coefficient, it can be seen the level of correlations between Nino 3.4 index and Biak monthly rainfall during the period of 1981-2010. The results are as shown in the Table 1. The 6th International Symposium for Sustainable Humanosphere Humanosphere Science School 2016 Bogor, 15 – 16 November 2016 80 Table 1. Correlation between Nino 3.4 index and Biak monthly rainfall in 30-years period Months R Correlation January 0,11 Negligible February -0,25 Weak March 0,01 Negligible April 0,05 Negligible May -0,46 Moderate June -0,26 Weak July -0,15 Negligible August -0,37 Weak September -0,50 Moderate October -0,55 Moderate November -0,08 Negligible December -0,16 Weak Table 1, showed the correlation between Nino 3.4 index and Biak monthly rainfall in the period of 30 years (1981-2010). It can be seen that the ENSO activities based on Nino 3.4 index, give dominant negative impact on the Biak monthly rainfall, meaning that when the warm ENSO activities index (positive) occurs, it can decrease Biak monthly rainfall. And conversely, if the cold ENSO activities index (negative) happens, there is an increase on Biak rainfall. However, the results varied from extremely weak levels (negligible) of relationship (January, March, April, July, August), weak correlation (February, June, August, September), until moderate correlation (May, September, October). And the highest correlation value is in the month of October with the r value reached -0.55 which means that the Nino 3.4 index had a strong enough (moderate) negative impact. Or in other words, when the ENSO activities occurs, it is able to influence Biak monthly rainfall strong enough, especially in October. During the period of 1981-2010, there were some cases when the El Nino activities precisely Biak monthly rainfall increased, while when the La Nina activities precisely Biak monthly rainfall decreased. However, the cases were not dominant results, because the percentage was only about 16.67 % of the El Nino and La Nina that occurred during that period. Factors triggering their minor cases that show the opposite effects of El Nino and La Nina in general are still not known for sure. This is because the phenomenon and oscillations that occur around the Pacific basin were not only El Nino and La Nina. There might be by PDO (Pacific Decadal Oscillation), ENSO Modoki, and others influence. PDO phenomena could affect the intensity of El Nino or La Nina event of the same period. When in the same phase to ENSO or the so-called constructive, PDO could amplify the intensity of El Nino and La Nina. However, if it was in opposite phase or the so-called destructive, the PDO could prevent the “true” impact of El Nino and La Nina. Then, the impact was an increased on rainfall in the central part of equatorial Pacific and the decreased in rainfall in western and eastern parts of equatorial Pacific when the El Nino Modoki activities. Meanwhile, La Nina Modoki impact decreased on the rainfall in the central part of equatorial Pacific and the increased on rainfall in the western and eastern region of equatorial Pacific. Besides these two phenomena, it was possible other combination factors such as sea surface temperature conditions in Indonesia. When the SST Indonesia experienced a warm anomaly, it had an impact on increasing the chance of rain in Indonesian region, including Biak. If warm anomaly of SST Indonesia coincided with ENSO events, the impact of the intensity of El Nino and La Nina also affected. In addition, there were also the cyclonic circulation occurred around the Pacific basin which could affected the impact of El Nino and La Nina. The 6th International Symposium for Sustainable Humanosphere Humanosphere Science School 2016 Bogor, 15 – 16 November 2016 81 Conclusion Research on the influence of ENSO activities against Biak monthly rainfall during the period of 1981-2010 has been completed using response analysis composite and correlation analysis. During this period, the frequency of El Nino events reached 33.33%, while La Nina reached 30.00%, while the neutral state reached 36.67%. These numbers indicated that the ENSO activities period nearing its normal period. ENSO activities during this period give considerable influence to Biak rainfall. From Biak monthly rainfall pattern was observed that the 1981-2010

period related to a shift in ENSO activities. In the El Nino events, the dominant pattern of normal rainfall had decreased or below normal. With a maximum decrease occurred in October, which reached 42.55% (95.4 mm). While the occurrence of La Nina, normal rainfall patterns predominant increased or tended to be above normal. With a maximum increase occurred in September, which reached 54.27% (115.4 mm). ENSO activities also affects the seasonal rainfall in Biak. The strongest influence of the El Nino and La Nina activities occurred in SON, namely the transition period from dry season to the rainy season in Indonesia. El Nino activities in SON triggered the largest decrease in rainfall of up to 27.08% (170.4 mm), while La Nina activities triggered an increase in the heaviest rainfall of up to 32.91% (207 mm). The smallest influence of El Nino occurred in MAM (the transition period from rainy season to dry season), while the smallest influence of La Nina occurred in JJA months (dry season in Indonesia). Correlation analysis revealed that the relationship between Nino 3.4 index and Biak monthly rainfall yield relationships that varies from negligible to quite strong (moderate). The highest correlation coefficient achieved in October indicating a negative relationship between the two variables were strong enough. Therefore, Biak which has equatorial rainfall type is moderately influenced by the activities of El Nino and La Nina. Instead of this, there were some minor cases opposite to dominant results. Because there were other oscillations influenced such as PDO and ENSO Modoki. Acknowledgment I am so honored and just want to deliver special thanks to Dr. Aries Kristianto, S.T., M.Si. for helping me to review the paper and Frans Kaisiepo from Biak Meteorological Station for the data. References Aldrian, E. (2002). Spatial patterns of ENSO impact on

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