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Spatial and temporal change of rainfall pattern in east coast of North Sumatera

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Abstract. The North Sumatera rainfall area is classified as equatorial type, which characterized by two peaks of maximum rainfall for each year and distribute evenly through the year with maximum 1 dry month. However, the occurrence of rainfall below normal in the period of January-April in 2014-2016 shows that there has been a change in rainfall patterns that can be caused by climate change. This paper aims to identify changes in rainfall patterns on the east coast of North Sumatera spatially and temporally. Over 16 years (1999–2014) monthly and annual rainfall data series in 74 locations along east coast of North Sumatera are selected for identifying the rainfall pattern change. The data was taken from private rain gauge and North Sumatra Agency for Meteorology, Climatology, and Geophysics (BMKG), which located along the east coast of North Sumatera. The observation on annual rainfall shows changes in rainfall patterns in the study sites would occur every 5-7 years. The occurrence of La Nina and El Nino also give a part on the change of annual rainfall pattern.

1. Introduction

Indonesia is an archipelago country located in the equator between 2 oceans and 2 continents, namely the Pacific and Indian oceans and the Asian and Australian continents. These conditions influence the climate conditions in Indonesia, especially rainfall. In general, rainfall type in Indonesia is divided into three types, namely the monsoonal, equatorial, and local [1, 2]. The main difference between these three types is the boundary between the rainy and the dry season. In the Monsoonal type, there is a strict boundary between the wet and dry seasons, while in equatorial types the rainfall tends to be evenly distributed throughout the year. The local rainfall type is strongly influenced by specific topographic conditions such as hills or mountains, the sea, and others.

Most regions in Indonesia have monsoon rain types, which can be seen from the high activity of convective clouds and the average rainfall pattern that in line with the Asian and Australian monsoon activity cycles. Beside the monsoon, other global climate indices such as Madden-Julian Oscillation, Inter-Tropical Convergence Zone (ITCZ), El-Nino Southern Oscillation (ENSO) and Indian Ocean Dipole Mode (IODM) also affect the weather in Indonesia [3-5]. Changes in rainfall patterns can occur during the El Niño and La Niña phenomena so that monthly rainfall patterns in Indonesia fluctuate [5-8]., such as drier during El Nino and wetter during La Nina.

North Sumatra has a characteristic climate and weather. This is due to the area flanked by two waters, namely the Indian Ocean in the West and the Malacca Strait in the East. Besides, there is Bukit Barisan Mountains that extend from North to South in the western part of North Sumatra province. In general, climate conditions in North Sumatra are the 800-4,000 mm/year of rainfall and evenly distributed throughout the year (dry months (rainfall below 60 mm/month) as much as 0-1 month / year), rainfall patterns are dominated by equatorial types, which has two rain peaks in a year that usually occur in March and September. The average air temperature is above 18^0C with solar radiation about 5 hours per day [9].

However, it was assumed that a climate anomaly had occurred on the east coast of North Sumatra that caused a change in rainfall patterns. There are several dry months occurrence or rainfall less than 60 mm / month which was found in January-April successively in 2014-2016. The incident occurred in almost all districts located on the east coast of North Sumatra, such as Serdang Bedagai, Langkat, Deli Serdang, Asahan, Simalungun, and Labuhan Batu. This rainfall anomaly causes disruption to the production of plantations and horticulture, especially on oil palm which are very vulnerable to water shortages that caused a productivity loss until 25% [9]. Palm oil is the main plantation product from North Sumatra which covers 1.46 million hectares or the second widest in Indonesia after Riau province.

Considering the large losses that occur due to the rainfall anomalies in the agricultural sector, especially on oil palm, it is necessary to conduct research on rainfall pattern anomalies on the east coast of North Sumatra. This study aimed to identify rainfall patterns and its changes that are analyzed spatially and temporally.

2. Methods

2.1. Study area

The research was conducted in the East coast of North Sumatra, which contained seven districts, such as: Serdang Bedagai, Langkat, Deli Serdang, Batubara, Asahan, Simalungun, and Labuhan Batu. It is located in the north of the equator between 1°- 4° N and 98° - 100° E. The boundary of the study area included in the north is the province of NAD and the Malacca Strait; in the South is the province of Riau; in the West are Karo, Samosir and South Tapanuli districts; and in the East is the Malacca Strait.

2.2. Observed data

Over 15 years (2000–2014) monthly and annual rainfall data series in several locations along east coast of North Sumatera are selected for identifying the rainfall pattern change. The data was taken from 74 rain gauge stations (Table 1 and Figure 1) which belong to North Sumatra Agency for Meteorology, Climatology, and Geophysics (BMKG) and also private or government oil palm plantations where located along the study area. The selected rain gauge stations are the station that has the most complete and reliable data during the time observation.

2.3. Methods

A simple regression analysis using Excel software was applied to study the data trend of the minimum rainfall data which divided into 3 types of data: annually, seasonal (January-June), and seasonal (July-December).

Data was processed temporally and spatially using ArcMap 10 software with the Spatial Analyst tool. The interpolation method used is Inverse Distance Weighting (IDW), which is the mostly applied and deterministic interpolation techniques in soil science field. The IDW method estimates an unknown value by determining the search distance, the nearest point, power and obstacles settings from nearby known observation points. The known sample points are implicit to be self-governing from each other [10].

The formula used is: $$z_p = \frac{\sum_{i=1}^{n}\left(\frac{z_i}{d_i^p}\right)}{\sum_{i=1}^{n}\left(\frac{1}{d_i^p}\right)}$$

Where z_p is the interpolated value, n representing the total number of sample data values, z_i is the *i*th data value, d_i is the separation distance between interpolated value and the sample data value, and p denotes the weighting power.

Table 1. Lists of rain gauge stations that used in the study

Station Name				
1. Sampali	16. G.Pamela	31. Aek Loba 2	46. Sei Dadap	61. Balimbingan
2. Polonia	17. Gunung Para	32. Aek Loba 3	47. Sei Silau	62. Bangun
3. Rambutan	18. Mata Pao 1	33. Aek Tarum 1	48. Serbangan	63. D. Merangir 1
4. Limapuluh	19. Mata Pao 2	34. Aek Tarum 2	49. Tanah Raja	64. D. Merangir 2
5. Pasir mandoge	20. Mata Pao 3	35. Aek Tarum 3	50. Aek Pamingke 1	65. D. Merangir 3
6. Tandem	21. D.Merangir 1	36. Aek Tarum 4	51. Aek Pamingke 2	66. D. Merangir 4
7. Btg Serangan	22. D.Merangir 2	37. Ambalutu	52. Labuhan Haji	67. D. Merangir 5
8. Kuala Bingei	23. D.Merangir 3	38. Bdr Selamat	53. Merbau Selatan	68. D. Merangir 6
9. Bukit Sentang	24. Sarang Giting	39. Bunut	54. Membang Muda	69. D. Sinumbah
10. Aek Pancur	25. Silau Dunia	40. Gurakh Batu	55. Negeri Lama	70. Kerasaan
11. Sungei Putih	26. Tanah Besih	41. Huta Padang	56. Perlabian	71. Laras
12. Tanjung Purba	27. Tjg Maria	42. Kwala Piasa	57. Rantau Prapat	72. Maligas
13. Timbang Deli	28. Lidah Tanah	43. Padang Pulau	58. Sisumut	73. Marjandi
14. Bangun Bandar	29.Tanah Gambus	44. Pulau Mandi	59. Sei Meranti	74. Marihat.
15. G Monako	30. Aek Loba 1	45. Sei Baleh	60. Bah Jambi	

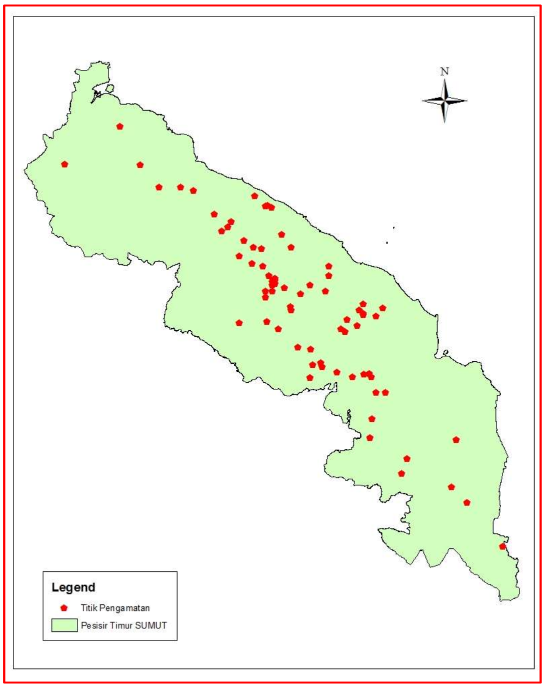

Figure 1. The 74 observed stations that distributed along east coast of North Sumatra province.

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3. Results

3.1. Regression analysis

Before IDW analysis was carried out, regression analysis of minimum annual and seasonal rainfall data (per 6 months: January to June and July to December) were conducted to see the tendency on increasing or decreasing rainfall amount on the study area during 14 years (2000-2014). The results showed in Figure 2, which can describe that the annual and seasonal rainfall (July-December) are tend to be stable, despite the fluctuating rainfall during the observation time. However, in seasonal rainfall for January-June, there is a tendency for the rainfall to decrease with the regression value y = -1.2902x + 65.592. The slope shows that there was a 20 mm decreasing of rainfall amount during the observation time. This shows that even though there is a decrease in rainfall amount at the beginning of the year, but it there is no tendency of decreasing rainfall amount at the end of the year. The decreasing rainfall in the beginning of the year and the stable rainfall in the end of the year make there is no tendency of decreasing rainfall amount in the annual minimum rainfall.

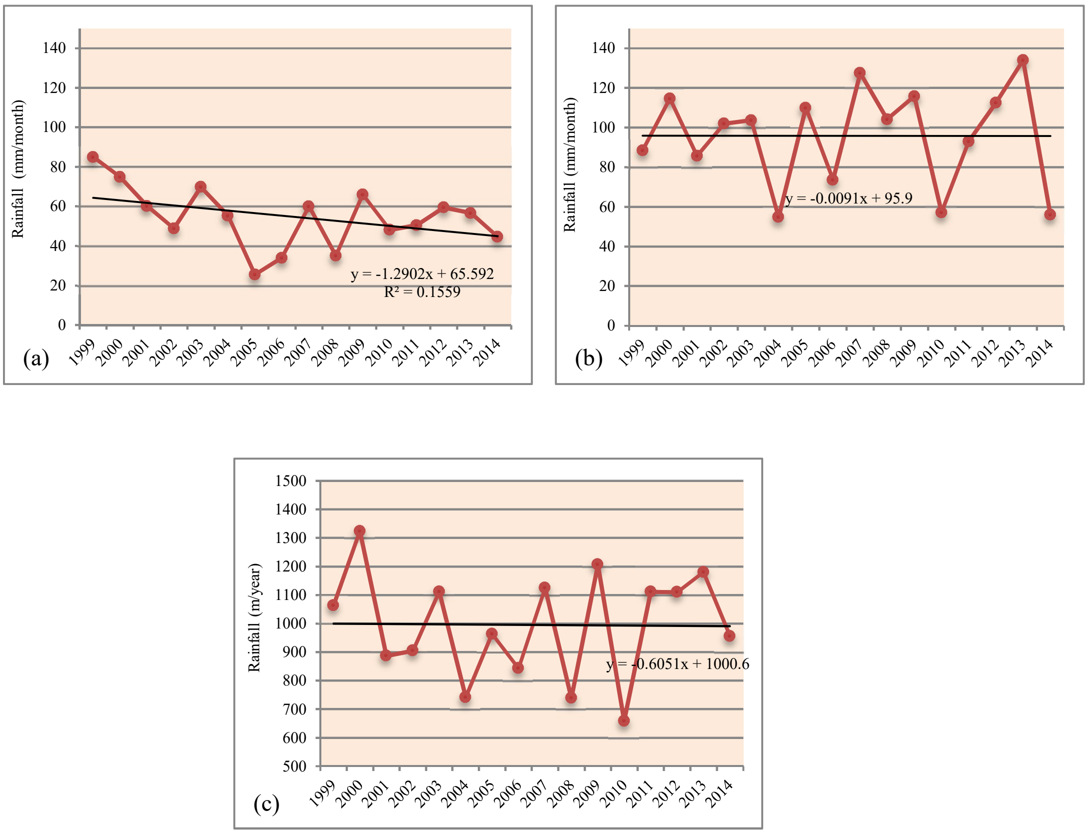

Figure 2. The regression analysis on annual and seasonal minimum rainfall data during observation time. (a) January-June; (b) July-December; and (c) Annually (January-December).

3.2. IDW Analysis

The Interval Distance Weighting (IDW) analysis was done using ArcMap 10 software. The analysis divides the rainfall amount on east coast North Sumatra into seven intervals of annually rainfall, namely (1) rainfall <1.500 mm/year; (2) rainfall 1.500-2.000 mm/year; (3) rainfall 2.000-2.500 mm/year; (4) rainfall 2.500-3.000 mm/year; (5) rainfall 3.000-3.500 mm/year; (6) rainfall 3.500-4.000 mm/year; and (7) rainfall > 4.000 mm/year. The intervals were shown by the color in the map. The lesser the rainfall amount was, the redder the color on the map, while if the rainfall value gets higher, the color will turn to green and blue (Figure 3).

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Most of the eastern of study area, the rainfall tends to be small (1.500-2.000 mm/year), namely in Langkat, Deli Serdang, and part of Asahan district. While in the western part of study area, namely Simalungun and Labuhan Batu districts, tend to be wetter. This is caused by the topography in the western part has begun to hilly with a fairly high elevation that is influenced by the Bukit Barisan platform. The area's most often affected by El Nino events are Langkat, Deli Serdang, and part of Asahan district, where each time El Nino occurs, the area became drier.

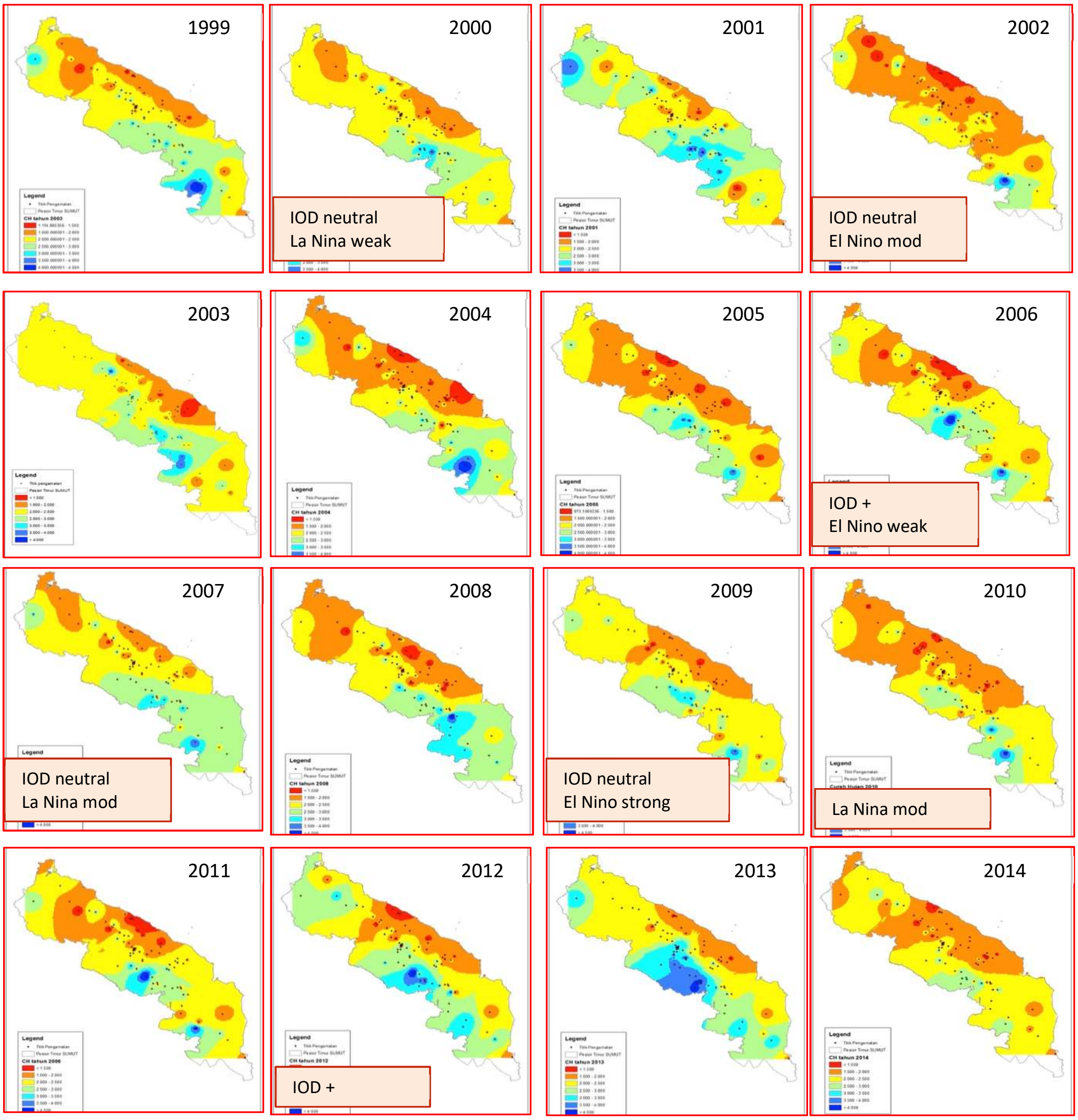

Figure 3. The IDW analysis of annual rainfall in east coast North Sumatera.

El Nino occurrence will affect rainfall in Indonesia that is become drier than usual. Even though Gustari [7] and Pradiko *et al* [9] stated that El Nino less influenced the northern Sumatra region, but apparently the results of spatial analysis showed that there was a rain pattern disturbance in the same year or a year after El Nino occurred. Even so, the positive IOD incidence does not appear to significantly affect rainfall patterns on the east coast of North Sumatra.

Based on the pattern of southern oscillation index and dipole index mode distribution (Figure 4), there were several occurrences of El Nino, La Nina, and positive IOD in the intervals of observation time. The El Nino with weak intensity occurred in 2006 and 2008, moderate El Nino in 2000, and a strong El Nino in 2010. Hereinafter, the weak La Nina incident took place in 2002, and moderate La Nina was happening in 2007 and 2010. Meanwhile, positive IOD events occurred in 2006 and 2012.

Visually, the changes in annual rainfall patterns appear to occur every 5-6 years. However, the occurrence of El Nino or La Nina phenomena causes outbreaks of pattern changes in the year or year after the phenomenon occurs which causes difficulty in determining the timing of changes in rainfall patterns.

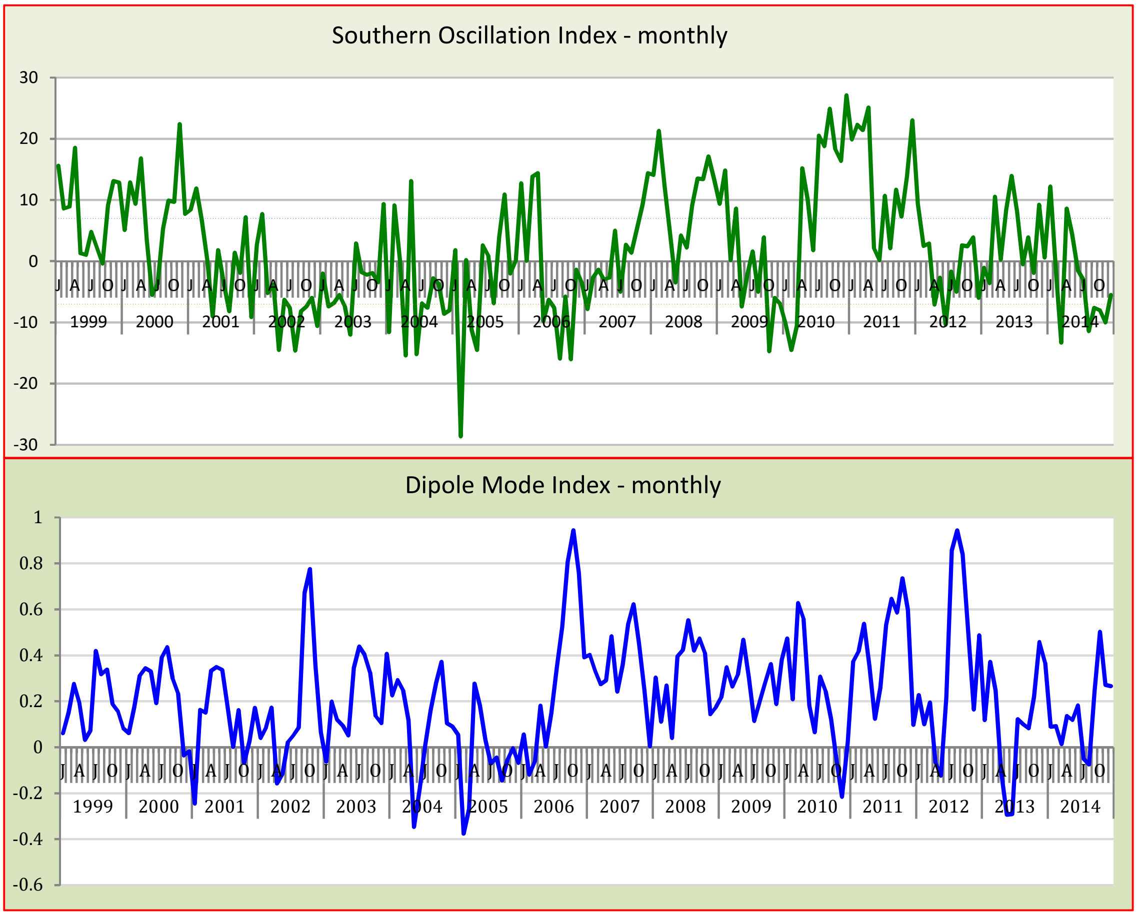

Figure 4. The monthly Southern Oscillation Index (above) and monthly Dipole Mode Index (below) during observation time.

4. Conclusion

Rainfall pattern on East Coast North Sumatra tend to change every 5-6 years. Climate anomaly such as La Nina or El Nino and positive or negative IOD caused interference on rainfall pattern, thus make it difficult to determine the time of changing.

5. Suggestion

It is necessary to observe more detailed in rainfall patterns change, such as 3 months or 6 months to obtain more accurate results. And also, it is necessary to determine which global climate phenomenon or its interaction that give the most influence in study area.

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