# CHARACTERISTICS OF CLOUD AND RAINFALL IN THE INDONESIAN MONSOONAL AREAS *)

***by : Bayong Tjasyono HK., Zadrach L. D., and Ina Juaeni***
***Department of Geophysics and Meteorology***
***Faculty of Earth Sciences and Mineral Technology***
***Institut Teknologi Bandung***

## Abstract

The Indonesian maritime continent receives sensible and latent heat in a large number. Troposphere over Indonesia is convectively unstable in all seasons. Convective clouds are dominant over Indonesia. The origins of these clouds are mainly due to instabilities in the troposphere coming from surface heating and orographic forcing. Most of the rainfall occur after the maximum insolation (afternoon) representing that rains fall from convective clouds. Heavy rains are frequently take place over monsoonal areas. A thunderstorm may result heavy rains up to one hour by rainfall exceeds 50 mm. ENSO years are associated with strongly decrease in rainfall and rice production due to the rice planting will be very late.

---

*) Submitted to International Roundtable on Understanding and Prediction of Summer and Winter Monsoons, Organized by NAM S & T Center India, BMG–Indonesia, NCMRWF Dep. S & T India, 21 – 24 November 2005, Jakarta / Bandung, Indonesia.

## 1. Introduction

The Indonesian region is the bigest island country in the world, it lies in the geographical latitude of $7^0$ 20' N to $14^0$ S and longitude of $92^0$ E to $141^0$ E. It has coastline about 43,673 mil or 80,791 km[1]. Atmosphere over Indonesia is complex and the formation of cloud is unique. The Indonesian region consist of 17,508 big and small islands with 70% is waters and only 30% is land, while above it there is atmosphere as far as the fringe of the earth or exosphere.

Besides it is passed by geographical equator, the Indonesian region is also passed by climatological equator namely the Intertropical convergence zone (ICZ) deplacing toward northern and southern hemisphere follows the annual migration of the sun from tropic of cancer to tropic of capricorn with delay against sun deplacement.

Indonesia is a part of earth system as a natural unity between lithosphere, hydrosphere, atmosphere and cryosphere. The earth is a member of solar system revolting around the sun through an elliptical orbit with the excentricity 0,017 and the period of one year. The earth rotates arround the imaginary axis by the period of one day (23 hours, 56 minutes, 42 seconds), so that the angular velocity of the earth's rotation is $7.29 \times 10^{-5}$ rad $s^{-1}$.

The impact of the earth's revolution and rotation is season namely winter, spring, summer, and autumn. The season of Indonesian region is categorized into rainy and dry seasons. The main factor determining the season is the number of rainfall. The onset of rainy season is determined by the number of rainfall 50 mm or more per 10 days and dry season is determined by the number of rainfall less than 50 mm per 10 days. When the monsoon is considered, the Indonesian region has 4 seasons namely ; west monsoon, east monsoon and two transition periods.

Climate of the Indonesian maritime continent is affected by some factors, such as Indian and Australian monsoons, sea surface temperature (SST) anomalies of Pacific Ocean (El Niño / La Niña) or Indian Ocean (Dipole Mode), local winds (sea – land breezes and anabatic – katabatic flows) and the annual migration of the sun. Figure 1, shows the geographical and meteorological position of the Indonesian maritime continent with respect to other oceans and continents in the world[1,2].

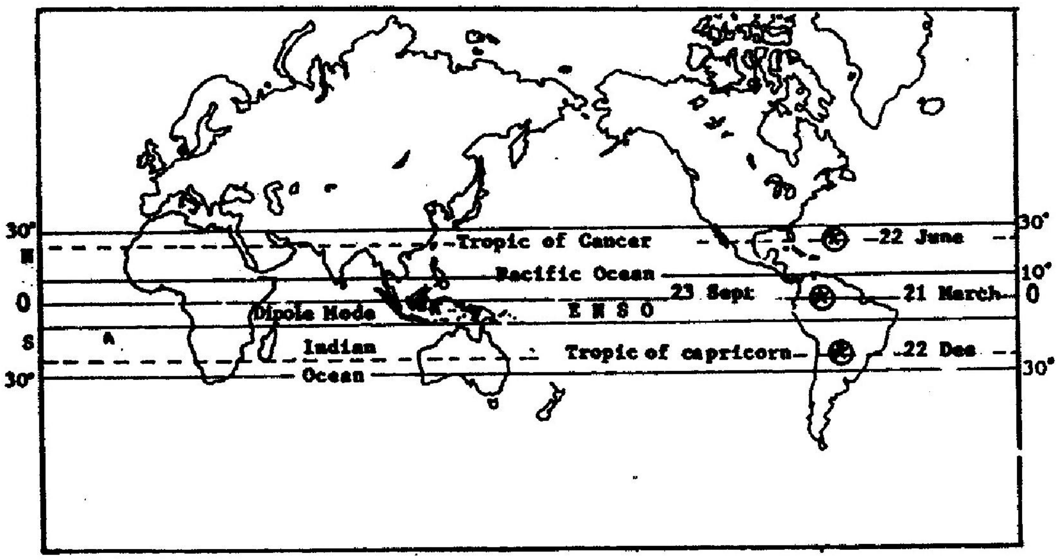


Figure 1. Geographical and meteorological position of the Indonesian maritime continent.

## 2. The Indonesian Maritime Continent as An Equatorial Monsoon Region

A main characteristic of the Indonesian region is the mixture of land (30%) and sea surface (70%), wich makes it a "maritime continent". This mixture and the montainous character of most island, create a large variation of local climates mainly depending on exposure to the monsoon and elevation. The Indonesian region is home to arround 215 Millions people (2003). Most of these people live directly and indirectly from what the land produce, so that the climate is very important factor in their lives.

As an equatorial region, Indonesia has a maximum insolation (incoming solar radiation) and latent heat of condensation released by change of water phase from vapor to liquid. Each gram of water vapor condensed to water droplet will released latent heat of about 2450 joule. On 21 March and 23 September occur equinoxes i.e., the position of the sun at the equator twice in one year. The impact of the equinoxes is marked in the monthly rainfall distribution showing double maxima[3], such as for station of Pontianak, Kalimantan, see figure 2.

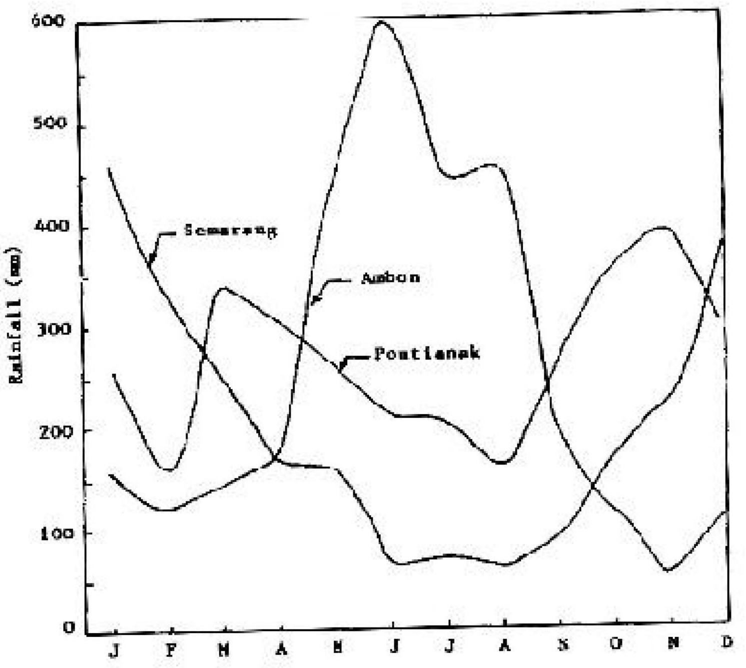


Figure 2. Monthly rainfall distribution for Pontianak, Semarang, and Ambon.

The term monsoon means season or "musim" in Indonesian language. The monsoon can be described as a giant sea breeze phenomenon by meridional (north–south) heat contrasts related to the annual migration of the sun[4]. The Indonesian region experiences giant sea breeze in consequence of it lies in between the two oceans (Pacific and Indian oceans) and the two continents (Asia and Australia Continents). Indonesia is affected by Indian and Australian monsoon having seasonal periods, it is longer than the periode of sea breeze as local winds. In summer the ocean to continent pressure gradient indicates availability of potential energy, on the contrary in winter occurs the continent to ocean pressure gradient due to the difference of heat capacity between ocean and continent. Monthly rainfall distribution of monsoon type is shown in figure 2.

The Indonesian maritime continent lies in the both northern and southern hemisphere, so that northeast Asian monsoon in northern hemisphere (NH) will make a bend to northwest monsoon when it passed geographical equator into southern hemisphere (SH) due to the Coriolis effect. On the contrary southeast Australian monsoon in southern hemisphere will make a bend to southwest monsoon in Indonesian northern hemisphere. As Bandung and Jakarta lie in southern hemisphere, the climatic system is affected by west monsoon component related to rainy season and by east monsoon component related to dry season.

In order to monsoon can be determined objectively, it is necessary to define monsoon index based on the surface windrose. Monsoon index $I_m$ is calculated by the expression as follows :

$$I_m = \frac{F_{Jan} + F_{Jul}}{2} \tag{1}$$

where $F_{Jan}$ and $F_{Jul}$ are frequencies of prevailing wind in January and July, respectively. The deviation of wind direction in January and July at least $120^0$. And area affected by monsoon when the monsoon index is 40 percents or more[5]. By using equation (1) it is obtained that average monsoon index are 64 and 51 percents for Bandung ($6.92^0$ S, $107.60^0$ E) and Jakarta ($6.17^0$ S, $106.82^0$ E) areas, respectively. For both values of monsoon index, it can be concluded that Bandung and Jakarta are monsoonal areas.

Orographic lifting is particularly efficient when monsoonal winds are forced to rise and converges with sea breeze and valley wind, as illustrated by the nothern coast of Central Java in the region of Mount Muria in December-January-February (DJF) is 1919 mm for station of Jepara (3 m, a.s.l), and 2367 mm for station of Bangsri (80 m, a.s.l), see figure 3. Mountain and highlands receive more rainfall than nearby lowlands due to orographic effect[6], especially on their windward sides. Generally rainfall increases up to about 1500 m but beyon this, it generally decreases with height.

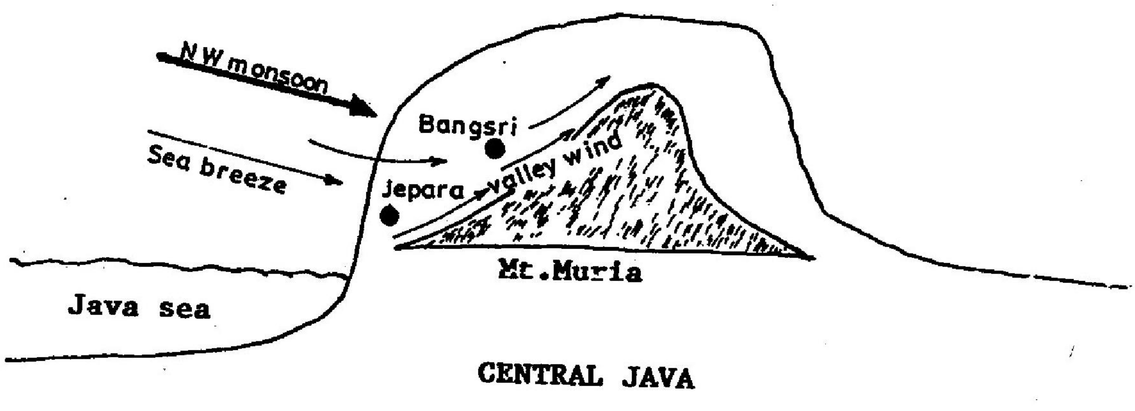


Figure 3. Reinforcement of monsoon by local winds (sea breeze and valley wind) and orographic effect.

## 3. Characteristics of Convective Cloud

The structure of convective clouds can be described by the vertical profile of equivalent potential temperature ($\theta_e$). In the adiabatic process, potential temperature ($\theta$) is a constant, an equivalent potential temperature ($\theta_e$) is also conservative in dry adiabatic or pseudoadiabatic processes.

It can be shown from figure 4 that equivalent potential temperature ($\theta_e$) is warmer in the convective cloud than that in non convective cloud or in the clear weather. The vertical profile of equivalent potential temperature shows a minimum in the lower middle troposphere up to level of 700 hPa. Lapse rate of the equivalent potential temperature ($\theta_e$) means that the lower troposphere is convectively unstable.

Figure 4, shows the vertical profile of equivalent potential temperature ($\theta_e$) over Jakarta in southern hemisphere mid summer (January) or rainy season and mid winter (July) or dry season. The lower troposphere in both of the seasons is convectively unstable.

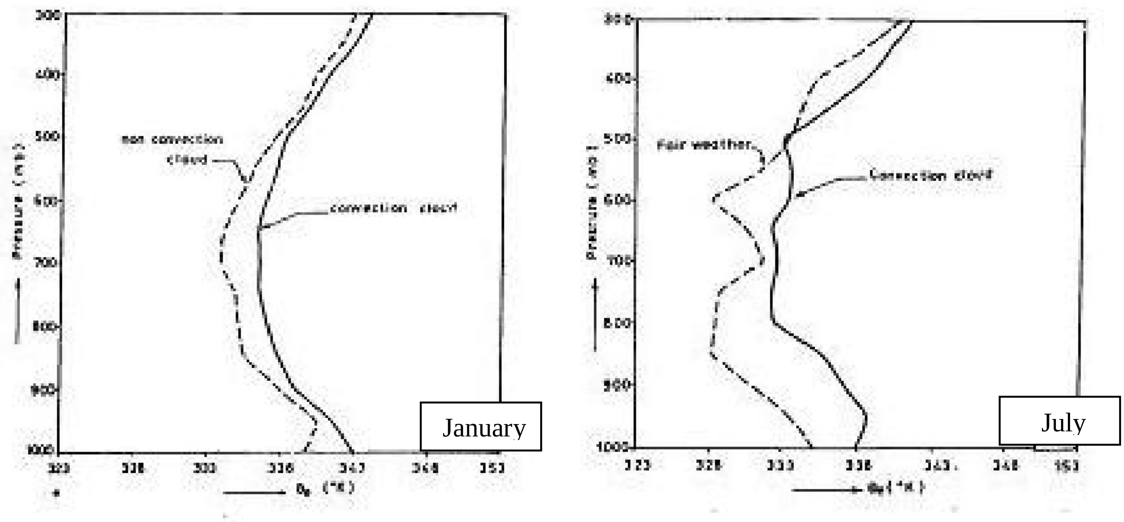


Figure 4. The vertical profile of equivalent potential temperature ($\theta_e$) over Jakarta in January and July.

Convective Condensation Level (CCL) may be assumed as height of cumuliform cloud base resulted by thermal convection from the earth's surface in consequence of solar radiation. Table 1, shows the height of CCL presented in hPa. Average convective condensation level is lower (962 hPa) in January than that in Juli (900 hPa). It means that the bases of convective cloud is lower in wet (rainy) season compared to in dry season.

Table 1. Height of the convective condensation level (hPa).

| Date | CCL July | Date | CCL July | Date | CCL January | Date | CCL January |
|---|---|---|---|---|---|---|---|
| 1 | 1006.0 | 16 | 859.1 | 1 | – | 16 | 963.6 |
| 2 | 912.9 | 17 | 865.8 | 2 | – | 17 | 969.7 |
| 3 | – | 18 | 872.9 | 3 | – | 18 | – |
| 4 | 901.9 | 19 | 963.7 | 4 | – | 19 | 956.9 |
| 5 | 897.1 | 20 | 894.6 | 5 | – | 20 | 949.7 |
| 6 | 863.0 | 21 | 825.1 | 6 | – | 21 | – |
| 7 | 903.9 | 22 | 881.1 | 7 | – | 22 | 958.3 |
| 8 | 855.5 | 23 | 885.3 | 8 | – | 23 | – |
| 9 | 827.0 | 24 | 1003.2 | 9 | – | 24 | 965.0 |
| 10 | 911.1 | 25 | 910.4 | 10 | – | 25 | 945.5 |
| 11 | 873.2 | 26 | 866.8 | 11 | 972.2 | 26 | – |
| 12 | – | 27 | 883.0 | 12 | 960.1 | 27 | 954.4 |
| 13 | 951.9 | 28 | 916.8 | 13 | – | 28 | – |
| 14 | – | 29 | 980.0 | 14 | 977.9 | 29 | 931.3 |
| 15 | 877.2 | 30 | 913.6 | 15 | 990.8 | 30 | – |
| | | 31 | 886.6 | | | 31 | 987.0 |

## 4. Frequency Distribution of Rainfall

The origine of convective clouds mainly due to instabilities in the troposfer coming from surface heating or free convection. The maximum insolation in the equatorial region occurs at 12.00 Local Time, and after this time the maximum convection to commence. Figure 5, shows average number of 3 – hourly rainfall from 00.00 LT up to 24.00 LT in Bandung. This figure indicate that most of the rainfall occur after 12.00 Local Time, it means the rainfall generally come from convective clouds after the maximum insolation.

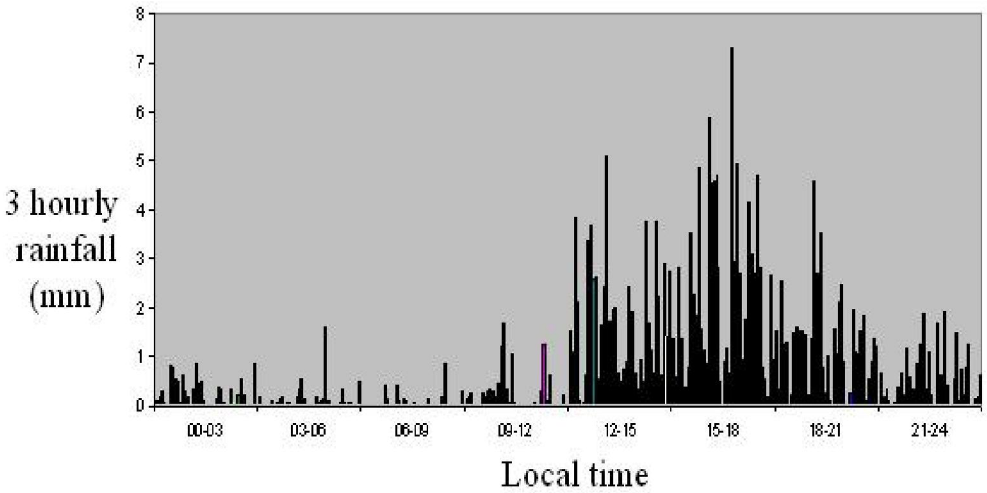


Figure 5. Average number of 3 – hourly rainfall from 00.00 to 24.00 LT in Bandung.

Table 2, shows the categories of rainfall intensity into very light rain (0.1 – 1.0 mm/h), light rain (1.1 – 5.0 mm/h), normal rain (5.1 – 10.0 mm/h), heavy rain (10.1 – 20.0 mm/h), and very heavy rain (> 20.0 mm/h) at the station of Bandung. In the monsoon area most rain falls in summer or in autumn. The summer maximum rainfall is associated with heat low intensification.

Table 2. Frequency distribution of rainfall in Bandung.

| Categories of rain fall intensity | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year : 2003** | **F r e q u e n c i e s** | | | | | | | | | | | |
| Very light rain | 4 | 2 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 3 |
| Light rain | 13 | 10 | 9 | 6 | 6 | 1 | 0 | 1 | 8 | 7 | 19 | 14 |
| Normal rain | 4 | 10 | 5 | 3 | 3 | 0 | 0 | 1 | 5 | 10 | 2 | 11 |
| Heavy rain | 2 | 4 | 6 | 2 | 4 | 3 | 1 | 3 | 3 | 2 | 5 | 2 |
| Very heavy rain | 0 | 1 | 11 | 3 | 2 | 0 | 1 | 0 | 0 | 4 | 2 | 1 |
| **Total** | **23** | **27** | **32** | **14** | **17** | **4** | **2** | **5** | **16** | **24** | **29** | **31** |
| **Year : 2004** | **F r e q u e n c i e s** | | | | | | | | | | | |
| Very light rain | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 1 |
| Light rain | 16 | 11 | 9 | 4 | 7 | 1 | 4 | 0 | 0 | 0 | 12 | 18 |
| Normal rain | 6 | 5 | 10 | 5 | 7 | 4 | 3 | 0 | 5 | 2 | 4 | 7 |
| Heavy rain | 4 | 5 | 1 | 1 | 4 | 1 | 2 | 1 | 1 | 0 | 4 | 10 |
| Very heavy rain | 3 | 0 | 1 | 5 | 7 | 0 | 0 | 0 | 2 | 1 | 2 | 2 |
| **Total** | **31** | **22** | **21** | **16** | **26** | **7** | **9** | **1** | **8** | **3** | **24** | **38** |

Heavy rainfall generally come from thunderstorm. A thunderstorm may yield heavy rains up to one hour by rainfall exceeds 50 mm. Figure 6, shows the heavy rains measured by automatic raingage at ITB, Bandung on 20th March 2003. The rainfall come from two cells of convective clouds. One cell yields amount of rainfall 36.8 mm in 45 minutes from 14.00 to 14.45 LT and the other cell yields amount of rainfall 73.7 mm in 1 hour 15 minutes from 20.15 to 21.30 LT.

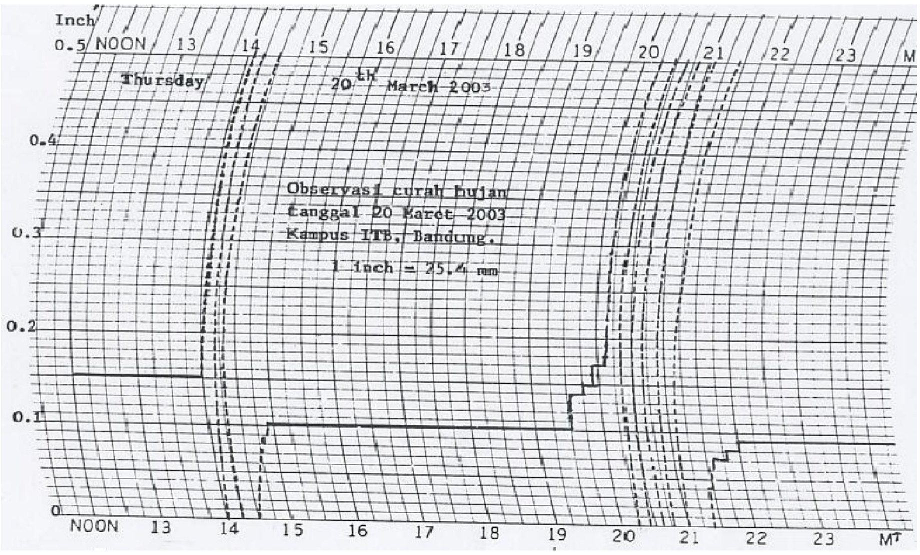


Figure 6. The heavy rains measured by automatic recording raingage at ITB, Bandung on 20th March 2003.

## 5. The Impact of ENSO on Rainfall and Agriculture

ENSO is a natural phenomenon emerging from coupled interaction between the atmosphere and the ocean in the tropical Pacific Ocean. El Niño (EN) as the ocean component and Southern Oscillation (SO) as the atmospheric component of ENSO. There is a profound impact of ENSO on humanity and society because of droughts, floods and other disaster that can severely disrupt agriculture, fisheries, the environment, health, the energy demand, air quality and so on. The influence of El Niño on the season in monsoonal areas is a longer dry season or a late begining of the rainy season.

The amount of rainfall at a level of 350 mm was proposed as a suitable criterion to indicate the end of the transition period in Indonesia[7]. The 350 mm criterion, mainly on account of its association with rice culture, for when this amount of rainfall after the 50th pentad (or the first week of September), the soil is generally sufficiently moistened to allow the farmers to prepare the seed beds for the rainy season rice crop.

Figure 7a and 7b, show the amount of cumulative rainfall from the 50th to the 73rd (December 31st) in monsoonal areas for Bandung and Jakarta respectively. It is evident that El Nino events cause long transition periods in comparison with the mean of a number of the years, such as in the El Nino 1997. Accordingly, El Nino event lengthen dry season or shorten rainy season, it means that rice planting will be very late.

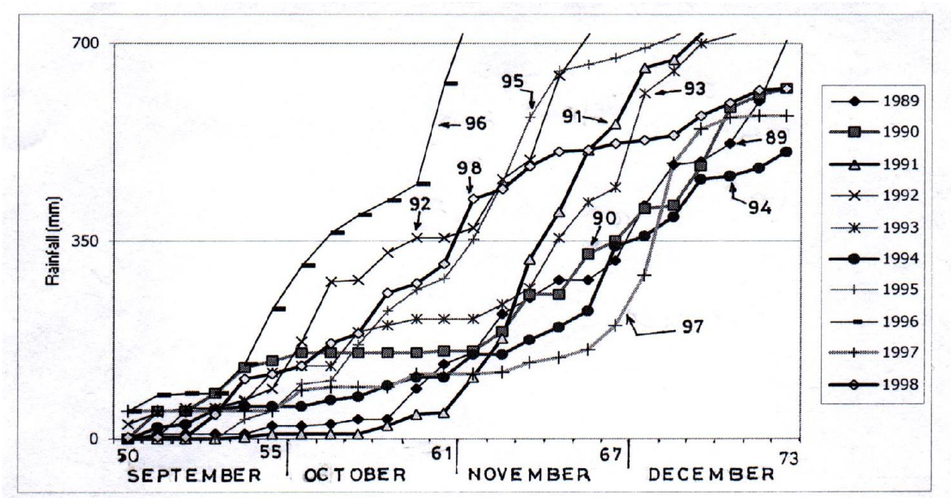


Figure 7a. Cumulative rainfall from the 50th pentad to 73rd pentad in Bandung area.

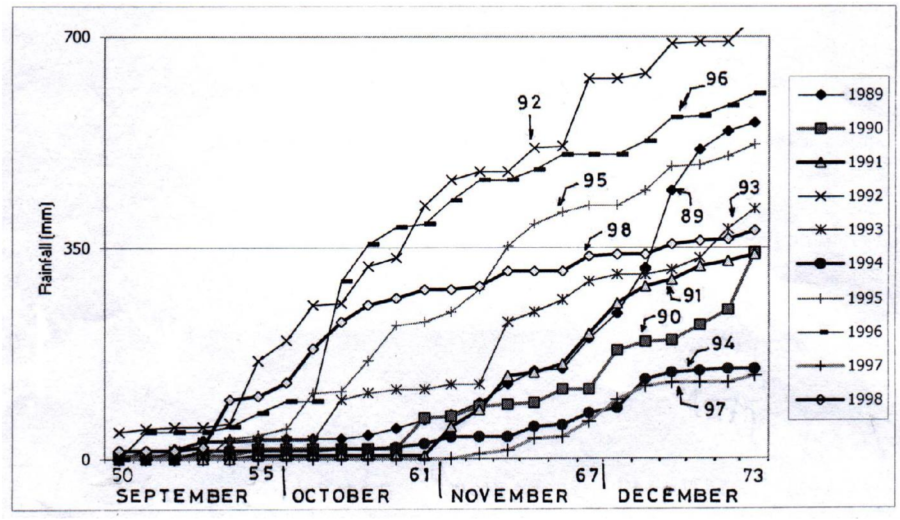


Figure 7b. Cumulative rainfall from the 50th pentad to 73rd pentad in Jakarta area.

## Clonclusions

The Indonesian region is governed by Indian and Australian monsoon. Due to the mixture of land and sea surface together with montainous character of the most islands, the Indonesian region creates a large variety of local climates. Reinforcement of monsoon by local winds and orographic effect produces an addition of the amount of rainfall up to about 1500 m in the windward side.

As an equatorial maritime continent, Indonesia has an insolation and latent heat in a large number. The impact of the equinoxes is indicated in the monthly rainfall distribution showing double maxima, such as for station of Pontianak.

Troposphere over Indonesia is convectively unstable. The maximum convection occurs after the maximum insolation or afternoon. In the monsoonal areas most of rainfall occur in summer and autumn. For southern hemisphere Indonesian region they occur in December- January- February, and March- April- May.

Large variation in weather and climate which is affected by monsoon and ENSO often a profound impact on humanity and society due to drought and consequently rice planting will be very late.

## Acknowledgements

The Author is gratefully thank the RUT XI project for funding this research via contract No.01/Perj/Dep.III/RUT/PPKI/II/2005.

## References

1. Dewan Hankamnas, 1996. Benua Maritim Indonesia, BPPT, ISBN 979 – 95038 – 1, Jakarta.
2. Bayong Tjasyono HK., 2004. State of the art study on meteorology in Indonesia, International Summer School, Kyoto Univ. – ITB Cooperation, KAGI 21, Bandung.
3. Bayong Tjasyono HK., 2000. Seasonal Rainfall Variation over Monsoonal Areas, JTM, Vol. VII, No. 4, FIKTM – ITB, Bandung.
4. Murakami, T., 2000. Tropical Meteorology, Lecture Note, Dept. Geoph. and Meteorol., ITB, Bandung.
5. Ramage, C. S., 1971. Monsoon Meteorology, Academic Press, New York.
6. Bayong Tjasyono HK., 1982. Orographic effect on the rainfall over Java in the Southeast monsoon period of 1979, Proc. of the International Conference on the Scientific Result of the Monsoon Experiment, WMO – BMG, Denpasar, Bali, Indonesia.
7. Schmidt, F. H., and J. Van der Vecht, 1952. East Monsoon fluctuation in Java and Madura during the period 1880 – 1940, Verhandelingen No. 43, Jakarta.