Flood Natural Disaster in Equatorial Monsoon Region *)

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Abstract

Severe weather is caused by meso or macroscale of weather system i.e., horizontal convergence of lower atmosphere accompanied by vertical air current and horizontal divergence of upper atmosphere accompanied by subsiding upper air current. The mixture of sea, land and the mountainous character of the Indonesian islands, creates a large variety of local climate. Equatorial monsoon flood natural disaster is meteorological phenomenon which frequently wash some places in the Indonesian region.

Flood natural disaster is occurred almost each year in monsoonal region, it is caused by torrential rains. From several cases of floods in Jakarta area, there were worst cases that are in 2002 and 2007, where they washed about 70% of the region. Flood is related to the low air pressure center, La Niña, negative Dipole Mode phenomena, and tropical cyclone in the near Indonesian waters. As a monsoon region, Indonesia suffer heavy rainfall, especially in hemisphere summer and autumn. Orographic effect in monsoonal region able to increase the amount of rainfall in the winward slope.

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1. Introduction

Indonesia is a part of the earth system as a natural unity between atmosphere, hydrosphere, litosphere and cryosphere (as on top of Mount Jaya Wijaya, Papua). The earth is a member of solar system revolting around the sun through an elliptical orbit with the excentricity is about 0.017 and the period of one year (365.3 days). The average distance of the earth from the sun is 93.0 x 10^6 miles (150 x 10^6 km), called one astronomical unit (1 AU). 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 :

$$\Omega = \frac{2\pi \text{ rad}}{23 \text{ x } 60 \text{ x } 60\text{s} + 56 \text{ x } 60\text{s} + 42\text{s}} = 7.29 \text{ x } 10^{-5} \text{ rad s}^{-1}$$

The impact of the earth's revolution and rotation is season namely; winter, spring, summer, and autumn. Base on the number of rainfall per decad (10 days), the season in Indonesia is categorized into rainy and dry seasons. The rainfall limit of the two seasons is 50 mm per decad. When the monsoon is considered, the Indonesian region has 4 seasons namely; northwest monsoon, southeast monsoon, two transition periods for southern hemisphere Indonesia, and northeast monsoon, southwest monsoon, two transition periods for northern hemisphere Indonesia.

The Indonesian region is governed by monsoon Australasia. Monsoon Asia is more humid, it causes rainy season and frequently flood events. While monsoon Australia is less humid, it causes dry season and frequently drought events. Flood disasters wash some places in the Indonesian region. The principle factors involved in the mechanism of flood is shown in figure 1.

Flood natural disaster affects the property damage, loss of life and economic impacts. In spite of flood is reported frequently through printed and electronic mass media, but the mechanism and factors causing flood is not paid attention seriously. From the number of flood natural disaster phenomena in Indonesia, it may be expressed that flood is caused by meteorological factor, especially climate element of rainfall.

Equatorial region may be defined as a region bordered by latitudes 10^0 N and 10^0 S or Coriolis parameter, $f = 2\Omega \sin \phi = 2{,}5 \text{ x } 10^{-5} \text{ s}^{-1}$, where ϕ is geographical latitude. At the equator (latitude 0^0), the Coriolis force toward zero. From this definition, the Indonesian maritime continent may be called the equatorial region. The Indonesian region is the bigest island country in the world which has coastline about 80.8 km[1]. The Indonesian regions consist of 17,508 big and small islands with 70% is waters and only 30% island.

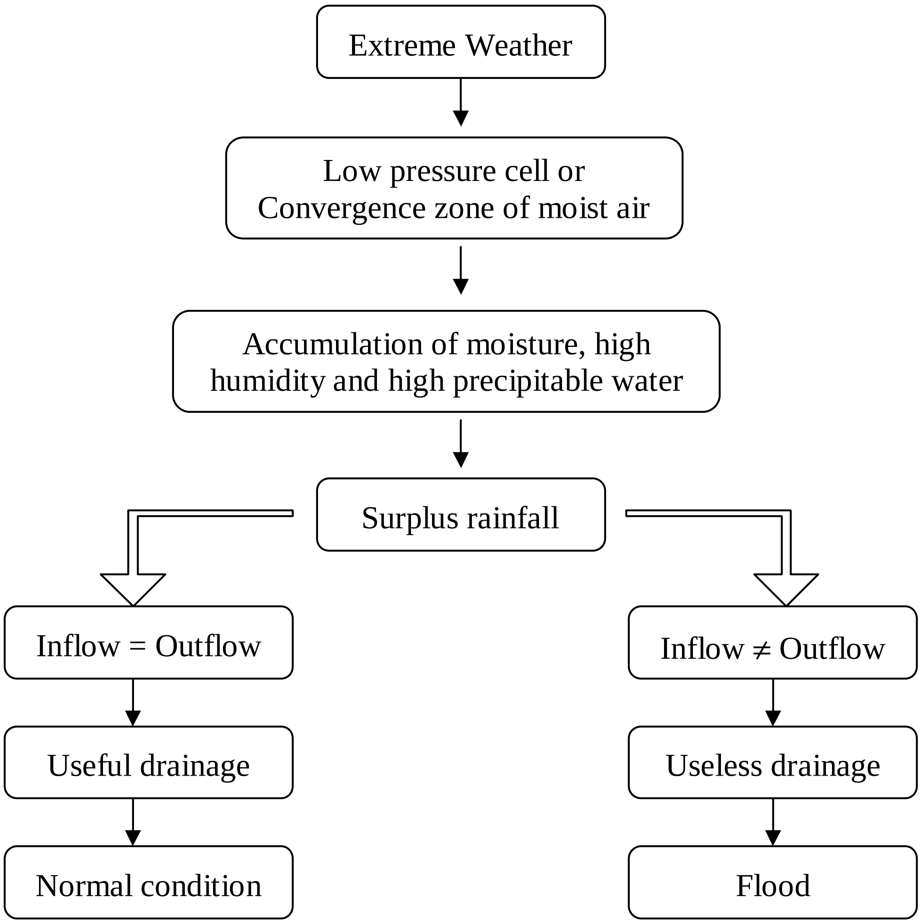

Figure 1. Diagram Schematic of flood events.

The Indonesian region is passed by climatological equator namely the Intertropical Convergence Zone (ICZ) deplacing toward northern and southern hemisphere follows annual migration of the sun from tropic of cancer on 22nd June to tropic of capricorn on 22nd December. Due to the Coriolis parameter is small, so that the tropical cyclone emerge rarely in Indonesia, but tropical depression may occur in the Indonesian waters[2,3].

2. Monsoon Circulation

Monsoon able to be assumed as giant sea breezes of seasonal period. Monsoon consist of two different seasonal circulation such as continental cyclonic inflow in summer and ciontinental anticyclonic outflow in winter. It means that the surface pressure gradient force changes in direction seasonally from ocean to continent in summer or from continent to ocean in winter, so that climate varies by season periodically, see figure 2.

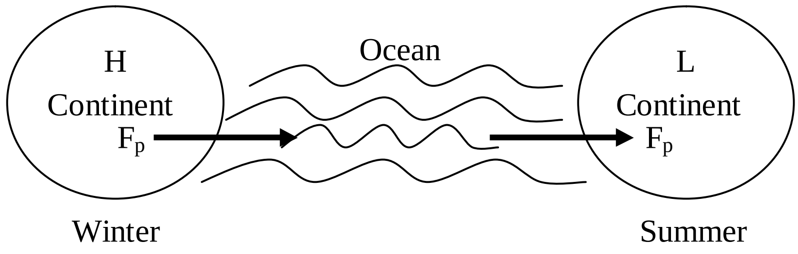

Figure 2. Scheme of monsoon circulation in the hemisphere summer and winter. F_p : pressure gradient force, L : low air pressure, and H : high air pressure.

The Indonesian monsoon is a part of the East and Southeast Asian monsoon. The direction of wind over the Indonesian region in boreal mid winter (January) and mid summer (July) may be seen in Figure 3. This figure shows paterns of average wind at altitude 2000 ft. In northern hemisphere winter (December, January, February), monsoon wind blows from Siberia region toward Australian continent. During this period go on west to northwest winds over southern hemisphere Indonesia, such as southern Sumatera, Java, Bali, Lombok, Nusa Tenggara up to Papua. Boreal winter monsoon is called northwest monsoon, while over northern hemisphere Indonesia, such as northern Sumatera and West Kalimantan, monsoon wind come from northeast direction called northeast monsoon.

In boreal summer, on the contrary wind blows from Australian continent toward Asian continent. In the region extends from the end of southern Sumatera, Java, Bali, Lombok, Nusa Tenggara up to Papua, wind direction from southeast called southeast monsoon, while over northern hemisphere Indonesia, wind blows from southwest toward northeast called southwest monsoon, see figure 3.

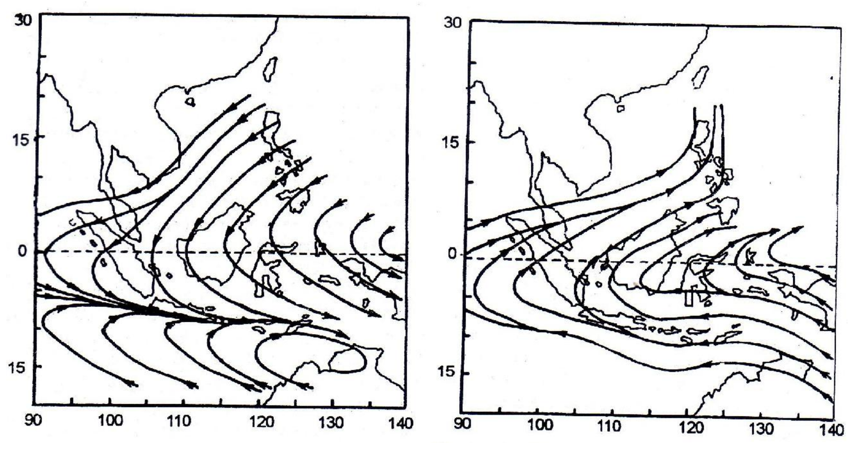

Figure 3. Mean wind patterns in January (left) and July (right)[4].

Table 1. Division of season based on the monsoon in Indonesia[4].

Southern Hemisphere Indonesia		**Northern Hemisphere Indonesia**	
Season	**Period**	**Season**	**Period**
Northwest monsoon	Dec – Jan – Feb	Northeast monsoon	Dec – Jan – Feb
First transition	Mar – Apr – May	First transition	Mar – Apr – May
Southeast monsoon	June – July – Aug	Southwest monsoon	June – July – Aug
Second transition	Sept – Oct – Nov	Second transition	Sept – Oct – Nov

3. Rainfall in Indonesia

In Indonesian monsoon, precipitation come from cumulonimbus, when vertical wind shear and lower troposphere convergence both are small, this precipitation is assigned the term showers or come from deep nimbostratus with embedded cumulonimbus, when vertical wind shear and lower tropospheric convergence both are large, this precipitation is called rains[5,6].

Rainfall is probably the most variable element of climate in the Indonesian equatorial monsoon. Almost everywhere in Indonesia the most important quantitative indicator, the annual total of rainfall differs from year to year and from place to place. Seasonal and diurnal rainfall distribution, rainfall intensity, rainfall duration, and frequency of raindays also indicate spatial and temporal variation. The main characteristics of the Indonesian equatorial monsoon rainfall, namely convectional rainfall, orographic rainfall and cyclonic rainfall near the Indonesian waters.

Convectional rainfall generally occurs over a limited spatial scale of between 10 – 20 km^2 and 200 – 300 km^2, its is therefore characterized by considerable spatial variability[6]. Convectional prepitation, because it is formed by rapid uplift, often to great heights in the atmosphere, is usually intense, occasionally it may be in the solid form of hail, see figure 4.

Figure 4. Hailstone in Wamena, Papua (Eastern Indonesia), 3 December 2007, Photo MetroTV.

Orographic rainfall is the result of condensation and cloud formation in moist air that has been physically forced over a mountain barrier. Orographic rainfall formation may be aided by convectional processes in the equatorial region. Orographic rainfall is limited to the mountains barrier. Because of orographic effects, mountain and highlands receive more rainfall than nearly lowlands, at least on their windward sides. Generally rainfall increases up to about 1000 – 1500 m but beyond this, it generally decreases with height. The height of the rainfall maximum for a location generally concides with the mean cloud base height at that location[7,8].

Cyclonic rainfall is produced by horizontal convergence of moist air in a circular area of low pressure where the maximum vorticity exist. In tropical cyclone where the combined processes of cyclonic inflow and convection produce very heavy rainfall. Tropical cyclone generally last between one day and one week. The area affected by cyclonic precipitation may be large, as tropical cyclones can move several hundred kilometers. Although the Indonesian equatorial archipelago has theoretically small influence of tropical cyclones, the weather in some parts of this region which is located near the tropical cyclone track can be affected, especially the increase of rainfall, wind speed and sea wave[3].

The Indonesian equatorial region is passed by climatological equator called the Intertropical convergence zone (ICZ), where the moist humid trade winds from either hemisphere meet. This ICZ is located in the equatorial low pressure area as a cloudy and weak wind, it is called as doldrum. ICZ displaces toward northern hemisphere in boreal summer and toward southern hemisphere in austral summer, following the annual migration of the sun. In January (austral maximum summer), the position of ICZ is about 15 ^{0}S over continent and near equator over ocean, see figure 5.

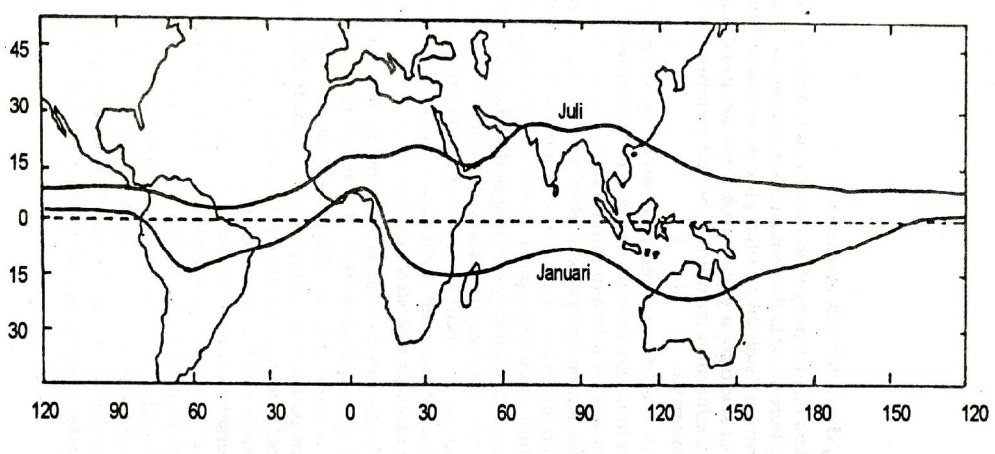

Figure 5. Mean position of ICZ in January and July[4].

4. Case Study : Flood in Jakarta Area

Jakarta area and its surroundings lie between Java Sea and Indian Ocean, see figure 6. In this area, convectional rains is affected by land and marin convective clouds. Based on this weather condition, Jakarta area experiences heavy rainfall especially in southern hemisphere summer and autumn. Jakarta area and its surroundings are washed by flood natural disaster every year due to torrential rains. Among them, the worst floods occurred in 2002 and 2007, where floods natural disaster washed over about 70% of Jakarta area.

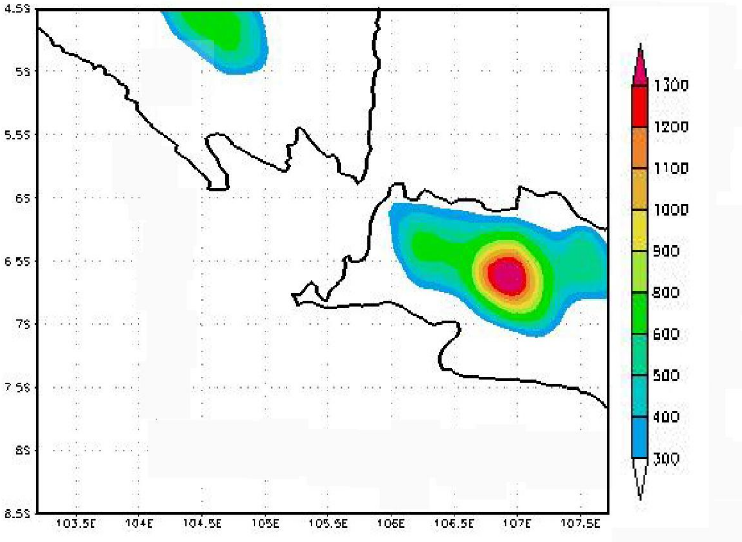

Figure 6. Topography map of research area.

Most of convectional rainfall occurs after the maximum insolation. In maritime region such as Jakarta area, the convection is also active at night, see figure 7.

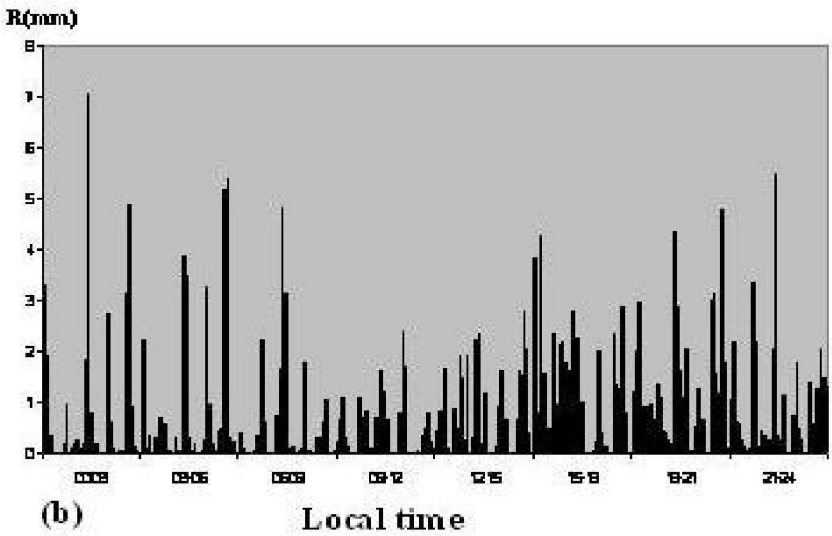

Figure 7. Distribution of 3 – hourly rainfall from 00.00 to 24.00 Local Time in Jakarta.

Figure 8 shows daily rainfall of flood phenomena in 2002, 2003, 2004 and 2007 in Jakarta area. The highest average daily rainfall of 143 mm and 180 mm occure in flooding on 29th January 2002 and February 2007 respectively. These number of daily rainfall may be categorized as extreme rainfall or extreme weather due to rarely occurrence.

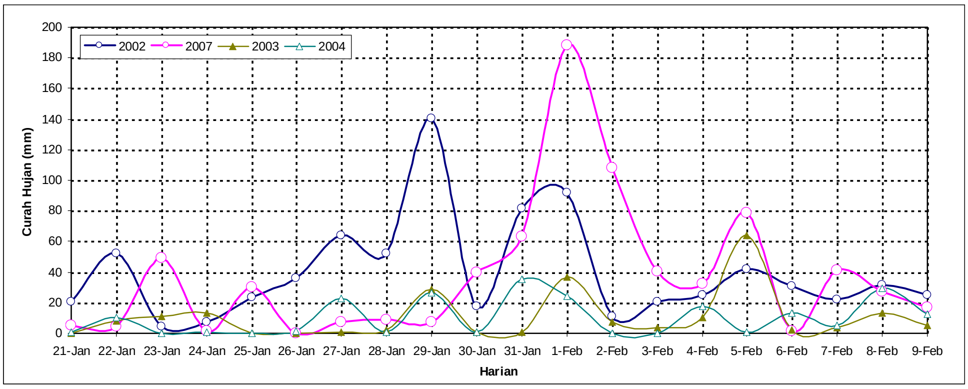

Figure 8. Average daily rainfall of 11 observation stations in 2002, 2003, 2004 and 2007, Jakarta area.

Figure 9, show daily isohyets in millimeters in Jakarta area and its surrounding. It can be seen that flood in Jakarta area is not only caused by rainfall in own area but it also is contributed by runoff from Bogor and Bekasi areas which the rainfall is more hevier compared the rainfall over Jakarta area.

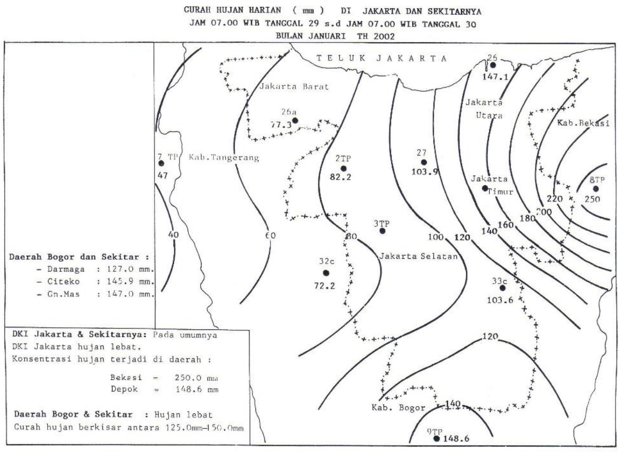

Figure 9. Isohyets (mm) over Jakarta area and its surrounding, 30th January 2002, 7.00 Local Time (Source BMKG).

Climate in Jakarta area controlled by Australasia monsoon, Indian and Pacific Ocean dipole, and cyclonic circulation near the Indonesian waters. Figure 10, shows cyclonic circulation when Jakarta area was washed worst flood disaster of extreme rainfall[9]. Wind vector showed cyclonic circulation in southern west Java when extreme rainfall occurred in 2002 and 2007. Cyclonic circulation cause a convergence of humid air. The number of rainfall is related to the streamlines pattern i.e., convergence at level of 850 mb accompanied by divergence at level of 200 mb, see figure 11.

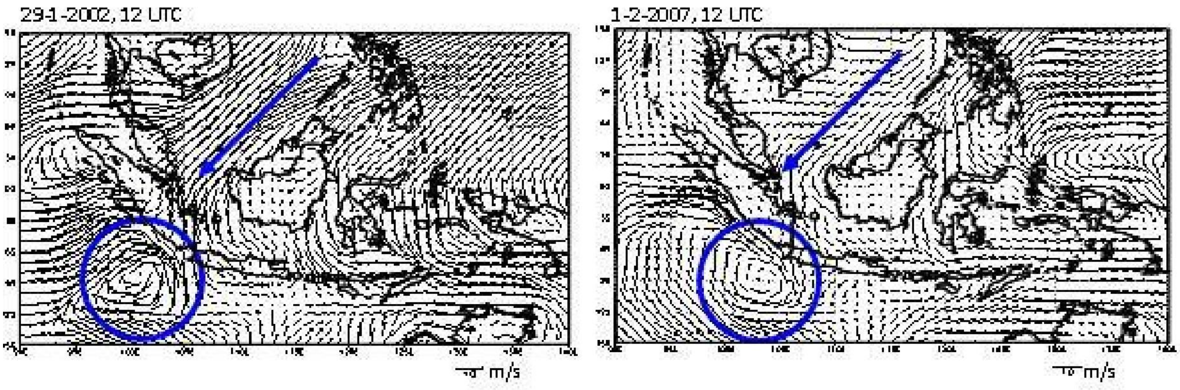

Figure 10. Wind vector (ms^{-1}) in cyclonic circulation at 12.00 UTC, 29 January 2002 and 1 February 2007.

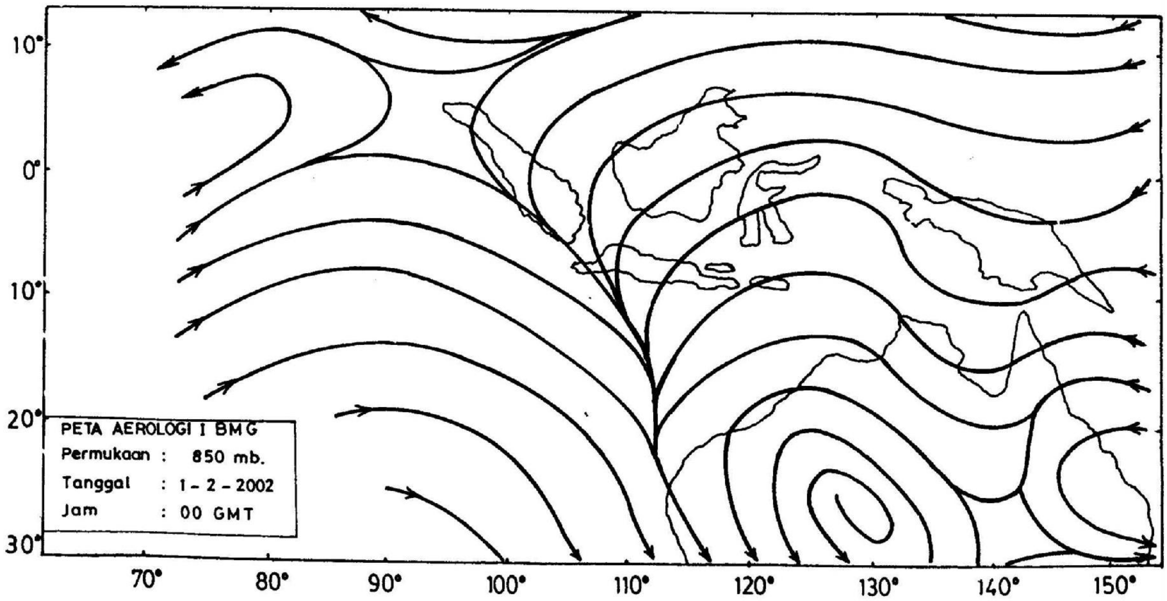

Figure 11. Streamlines of surface air (850 mb), 1 February 2002, 07.00 Local Time when flood disaster occurred in Jakarta area and its surroundings.

Indian and Pacific Ocean Dipole is determined by the difference of sea surface temperature (SST) in western and eastern ocean. El Niño event is warm episode and La Niña event is cold episode of central and eastern Pacific Ocean. Indian Ocean Dipole (IOD) positive when SST in western is warmer than that in eastern Indian Ocean, and IOD negative when SST in eastern is warmer than that in western Indian Ocean[10], see figure 12.

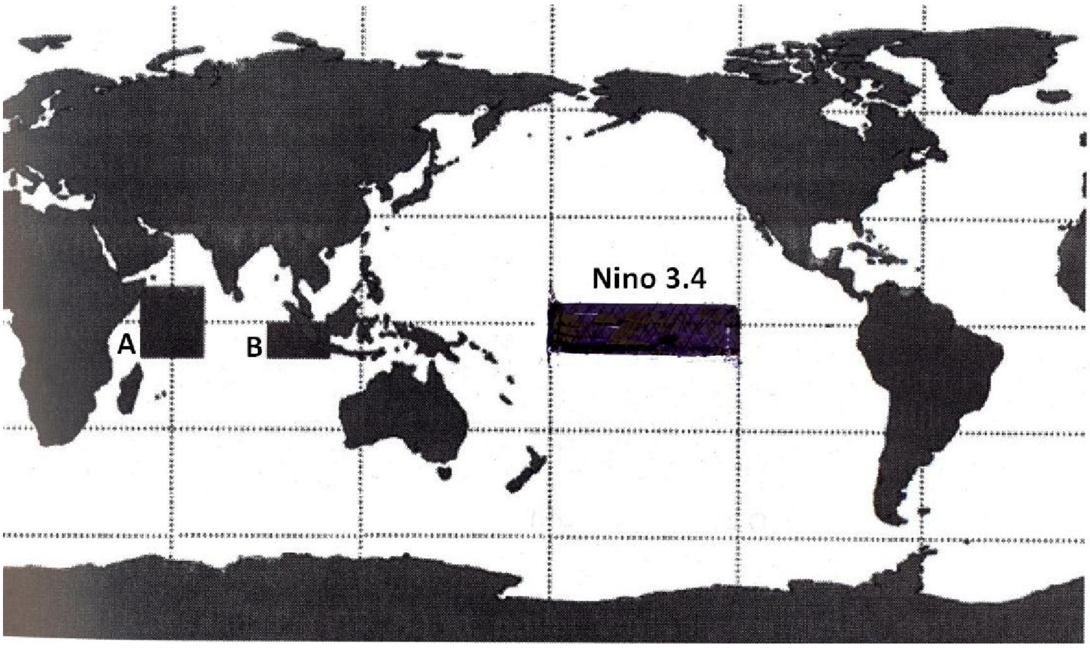

Figure 12. Area SST in Pacific ocean (Niño 3.4) and Indian Ocean (Box A and B).

Flood natural disaster in Jakarta area and its surroundings are related to negative Indian Ocean Dipole and Pacific Ocean La Niña events. These events describe that the Indonesian waters is warmer than that in the western Indian Ocean and in the estern Pacific Ocean, so that atmosphere over Indonesia is convectively more unstable than that other equatorial waters. In this condition, convectional rain is more active in Jakarta area and its surroundings. Figure 13 and 14, show negative Indian Ocean Dipole (Dipole Mode)[10] and La Niña events.

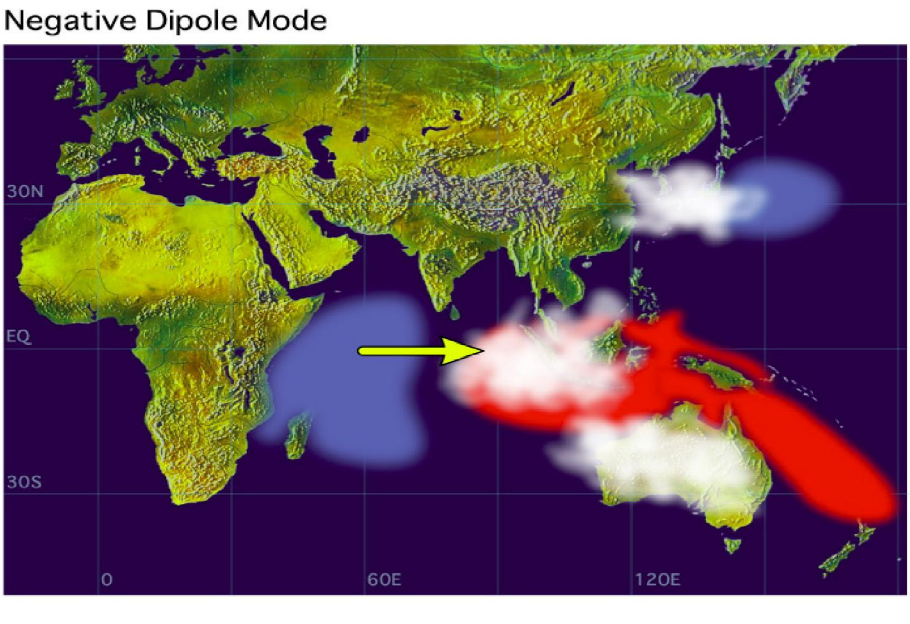

Figure 13. Negative Dipole Mode

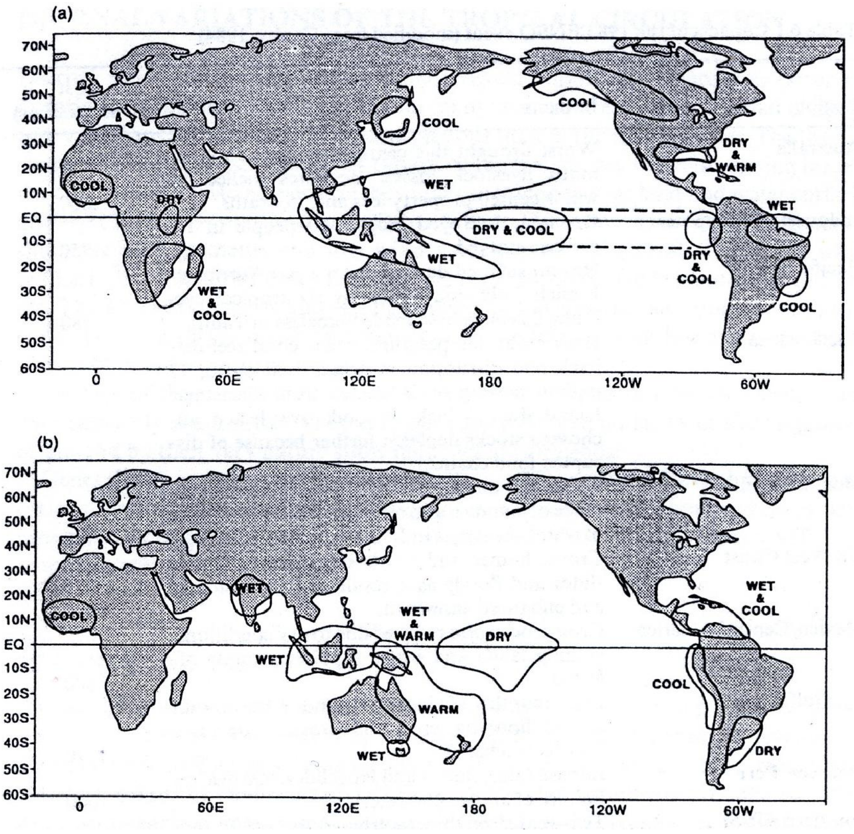

Figure 14. The Impact of La Niña (the antithesis of El Niño) events for (a) December to February, (b) June to August[7].

Conclusions

- Monsoon consist of two different circulation i.e., continental cyclonic inflow in summer and continental anticyclonic outflow in winter. Cyclonic inflow from ocean to continent yield an accumulation of air humid which cause heavy rain.
- Flood natural disaster is occurred each year in equatorial monsoonal area, especially in hemisphere summer. For several cases of floods in Jakarta area and its surroundings, there were worst cases that are in 2002 and 2007.
- Flood in Jakarta area and its surroundings is caused by mesoscale weather system such as the displacement of the intertropical convergence zone (ICZ) following annual migration of the sun. It is also related to the negative Dipole Mode, La Niña events, and the cyclonic circulation.

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