Climatology of South – East Asia Region *)

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Abstract

The number of meteorological station in general is small in the South – East Asia Region, particularly in mountainous areas. During the Second World War and the Vietnam War these was an interruption in weather observation, so that it necessary to use old soucers which are often with small accuracy.

South–East Asia Region is generally affected by Indian monsoon or Australasia monsoon. This region covered by tropical atmosphere. Meteorologist often use the boundary to define tropical atmosphere by using the latitude of 30^0 N and 30^0 S, which is known as "horse latitude", but the others use the latitude 23.5^0 N (tropics of Cancer) and 23.5^0 S (tropics of Capricorn).

The Walker circulation is a zonal circulation along the equator indicated by the air mass increase in the western and decrease in eastern Pacific. The warm episode in the central and eastern Pacific Ocean is called the El Niño years, and the cool episode is called the La Niña years. The Walker circulation intensity is recognized through the variation in sea surface temperature (SST). The sea–atmosphere coupling event is called ENSO (El Niño – Southenr Oscillation). ENSO causes a rainfall deficiency and a long drought in Indonesia and Philippine.

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Solar Radiation

The earth as a solar system, revolves around the sun through elliptic orbit with eccentricity of 0.017 and 1 year period (365.3 days). The earth also rotates on its imaginary axis with in 1 day period (23 hours, 56 minutes, 42 seconds) with the angular speed of the earth's rotation is : $\Omega = 2\pi$ rad/day = 7.29×10^{-5} $rad.s^{-1}$. Eccentricity (e) is the ratio between the distance of two focus (d) and the major axis of ellipse (a) pr e = d/a, for circular orbit, e = 0. According to Kepler law, the earth is located on any focus.

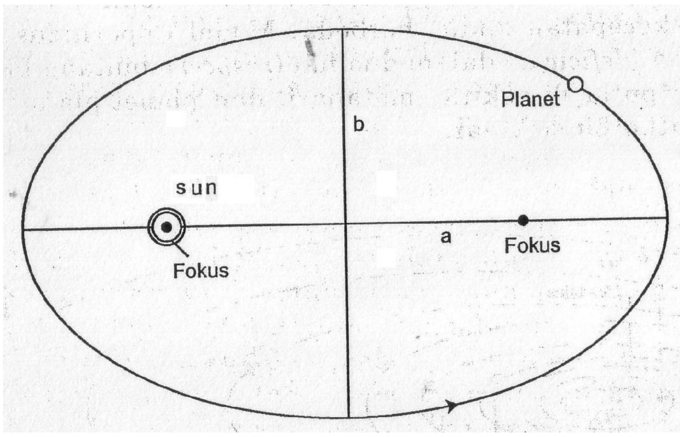


Figure 1. Orbit of the earth about the sun.

The mean distance of the earths from the sun is about 93,0 million mile or 150 million kilometer, it is called one astronomic unit. The distance of the earth from the sun in aphelion is 94,5 million mile and its distance in perihelion is 91,5 millions mile. The solar radiation per area unit that falls at the tops of atmosphere before experiencing attenuation (reflection, absorption, scattering) at the mean distance of 150 million kilometer is called as the solar constant that equals $\simeq$ 2.0 $cal.cm^{-2}$ mnt^{-1}. Solar radiation received on earth is called insolation (incoming solar radiation).

The sun is the main climatic control, and the insolation is the driving force of the atmosphere. Almost all the energy used by nature or by man is derived from the sun : even coal and oil are sources of **fossil energy** derived from the sun in past ages. The energy is received from the sun in the form of short wave radiation which penetrates the atmosphere except for a certain loss due to absorption, scattering and reflection. Some of the energy received at the earth's surface is also lost by reflection especially over snow and water surfaces. Therefore, the main radiation or energy source for the earth is the sun.

The energy is carried to earth by electromagnetic radiation. It travels at speed of light in the form of waves which, like sea waves. Solar radiation is referred to as **shortwave** radiation and has wavelengths between 0.15 and 3.0 μm. Radiation with wavelengths between 3.0 and 100 μm (micrometer) is referred to as **longwave** or infrared radiation. In the earth's atmosphere or at the earth's surface, radiation can be absorbed, reflected, transmitted or re–emitted.

Several laws describe the characteristics of emitted radiation, based on the black body concept. The quantity of radiation emitted by black body per second per area unit is :

$$E_b = \sigma T^4 \quad (1a)$$

called as the Stefan–Boltzmann law, where $\sigma = 56.7\ nWm^{-2}\ K^{-4}$ ($1\ nW = 10^{-9}\ W$) called Stefan–Boltzmann constant, and T is absolute temperature. If the object is not a perfect black body (gray body), the equation (1a) can be expressed as :

$$E_b = \varepsilon\sigma T^4 \quad (1b)$$

where ε : emissivity is a measure of the ability of a body to emit the radiation. For black body $\varepsilon = 1$ and gray body $\varepsilon < 1$. Typical emissivity values for natural materials are given in Table 1.

Table 1. Emissivity values for natural materials (Mc Gregor and Nieuwolt, 1998)

Material	ε (Emissivity)
Soils (dark wet to light dry)	0.90 – 0.98
Desert	0.84 – 0.91
Grass (long to short)	0.90 – 0.95
Agricultural crops	0.90 – 0.99
Deciduous forests	0.98
Water	0.92 – 0.97

For a given temperature there is a single peak of emission at one wavelength. The wavelength of peak emission (λ_{max}) may be estimated using Wien's displacement law expressed as :

$$\lambda_{max} = \frac{a}{T} \qquad (2)$$

a = 2897, when λ_{max} in micrometer and T in Kelvin. The higher the absolute temperature (T), the shorter the wavelength Figure 2, for the cases of 6000 K and 300 K which are representative absolute temperatures for the sun and the earth.

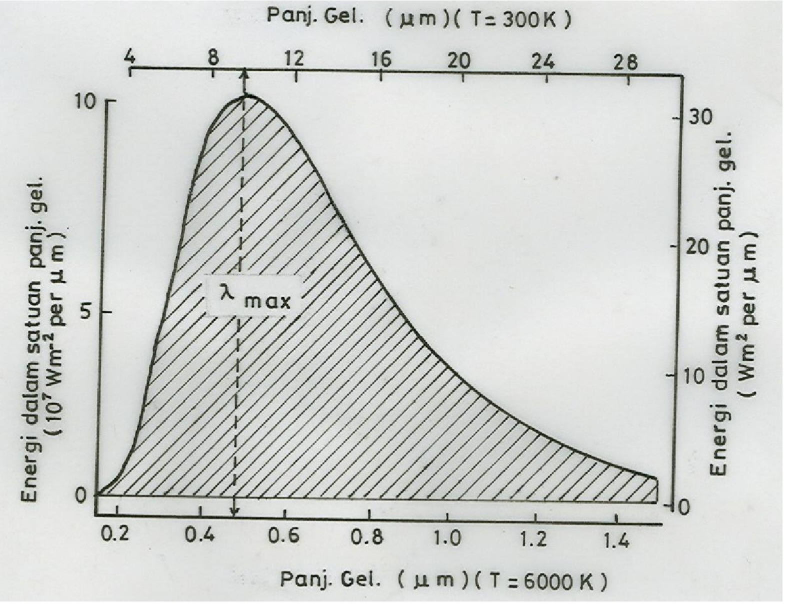


Figure 2. Distribution of radiant energy from a black body at 6000 K (left hand side vertical and lower horizontal axes). Peak emittances are in the shortwave range of 0.4 to 0.6 μm for the sun (6000 K) and the longwave range of 8 to 12 μm for the earth (300 K). From Mc Gregor and Niewolt, 1998.

The two earth's rotation and revolution mouvements cause annual migration of the sun from tropic of Cancer on 22 June to ewuator latitude 0^0 on 23 September to tropic of Capricorn on 22 December and back to the equator on 21 March. The effect of the annual migration of the sun in the four seasons : summer, autumn, winter and spring, see figure 3. The position of the sun above the equator is twice per year i.e., on 21 March and 23 September called equinoxes.

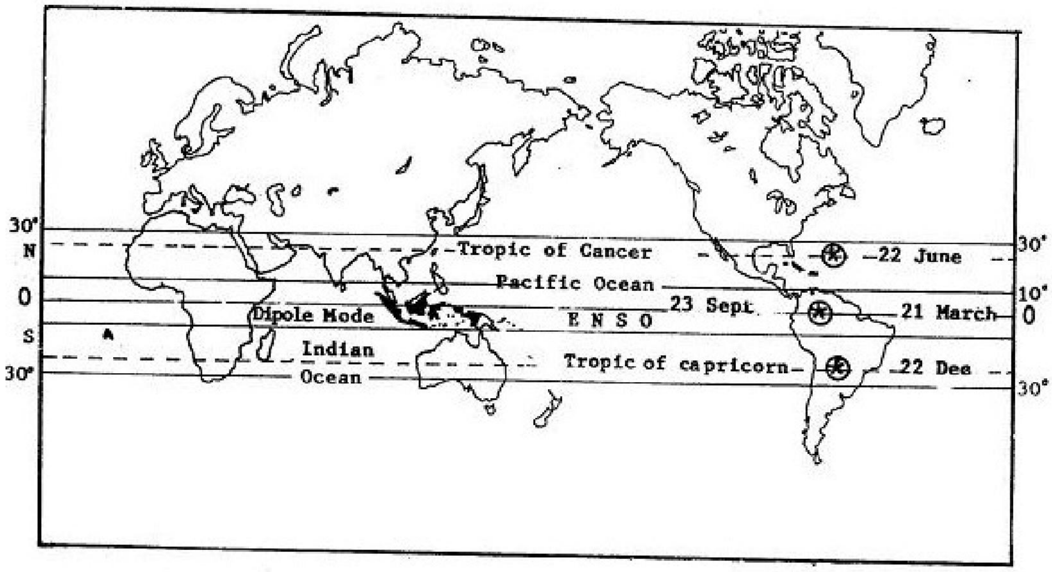


Figure 3. Annual migration of the sun.

The Monsoons

The word **monsoons** means **season** or mausin in Arabian language or musim in bahasa Indonesia, it implies a change in direction of the surface pressure gradient and in prevailing weather. The pressure gradient force (F_p) can be expressed as :

$$F_p = -\frac{1}{\rho}\frac{\partial p}{\partial n} \qquad (3)$$

The negative sign indicates that the direction of pressure gradient force is from high pressure cell toward low pressure. The geostrophic wind (V_g) is expressed by :

$$V_p = \frac{1}{\rho f}\frac{\partial p}{\partial n} \qquad (4)$$

Where :

∂n : distance of two isobars

∂p : the difference of high and low pressures

ρ : air density

f : Coriolis parameter, $f = 2\,\Omega \sin\phi$

Ω : angular velocity of the earth's rotation in the north pole, and in latitude of ϕ is $\Omega \sin\phi$.

Geostrophic wind occurs when Coriolis and pressure gradient force will be acting in opposite directions. The Coriolis force (F_c) = fV, where V is wind speed, see figure 4.

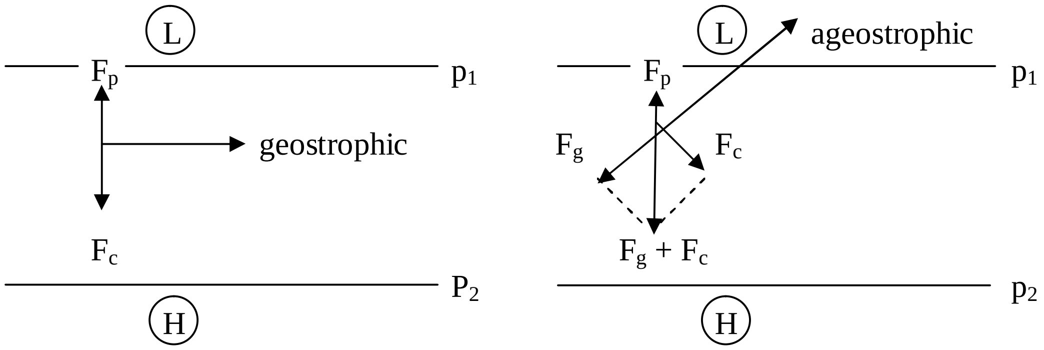


Figure 4. Geostrophic wind (left) and ageostrophic wind (right) in northern hemisphere. H : high pressure, L : low pressure, p : air pressure
F_p : pressure gradient force, F_g : frictional force, and F_c : Coriolis force.

The forces that generate air motion are the pressure gradient force (F_p), the Coriolis force (F_c), the frictional force (F_g) and gravity. As gravity only varies by an in significant amount, only 0.5% from the equator to the poles (gravity is small at the equator), the gravitional force is not usually considered in discussions about atmospheric motion.

The monsoon comprises two distinct seasonal circulation, that are : a winter outflow from a cold continental anticyclone and a summer inflow into a continental heat flow, see figure 5.

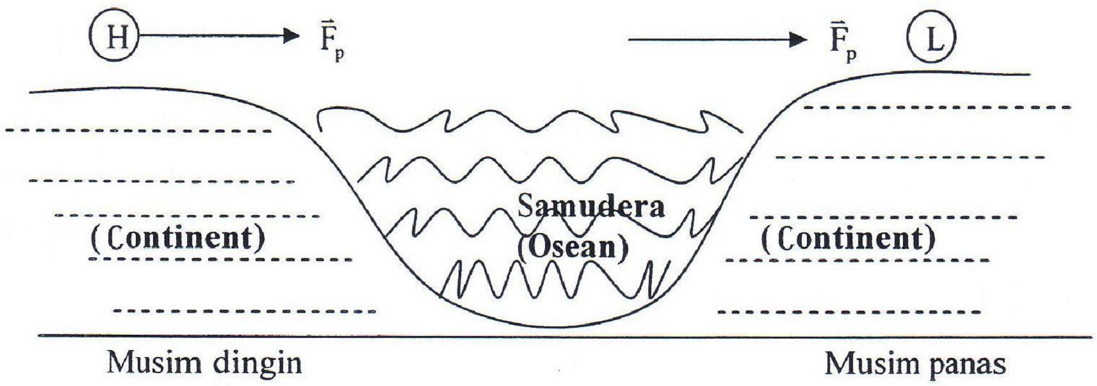


Figure 5. Monsoon system.

The main characteristics of the monsoon regions are as follows :

i. the prevailing wind direction deviates by at least 120^0 between January and July.

ii. the average frequency of prevailing wind direction in January and July is more than 40%.

iii. less than one cyclone–anticyclone alternation occurs on average every two years in any one month in a 5^0 latitude – longitude rectangle.

iv. the mean resultant winds in at least one of the months exceeds 3 ms^{-1}. (Ramage, 1971).

The resultant wind speed (V) :

$$V = \sqrt{V_x^2 + V_y^2} \quad \text{or} \quad \vec{V} = \vec{i}V_x + \vec{j}V_y \qquad (5)$$

where :

V_x : zonal (W – E) wind speed

V_y : meridional (S – N) wind speed

The monsoon regions of the world according to these characteristics are shown in figure 6.

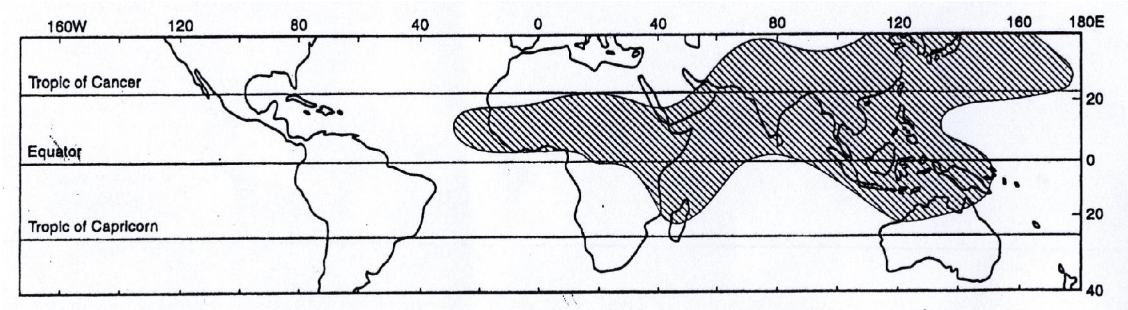


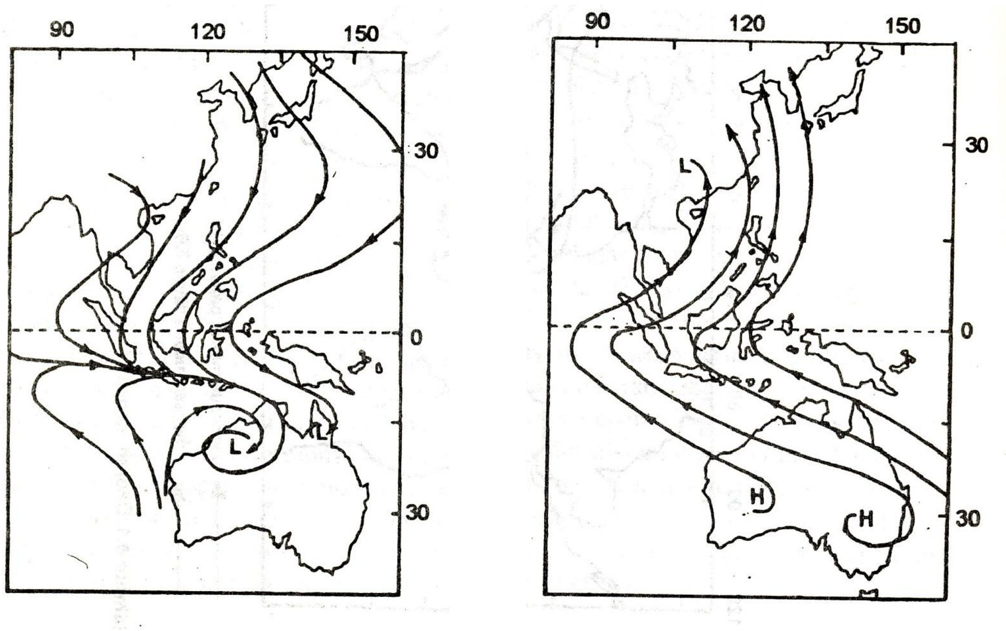
Figure 6. Areas with monsoon circulations according to the criteria of Ramage (1971).

Three general factors for the existence of the monsoons are :

i. The differential seasonal heating of the oceans and continents. Important seasonal temperature and pressure changes take place. Seasonal contrasts in land surface temperature produce atmospheric pressure changes which produce seasonal reversals of the pressure gradient force, the basic driving force of winds, so that there are major seasonal wind reversals which are referred to as **monsoon**.

ii. Moisture processes in the atmosphere. As moist air rises over summertime heated land surface, then the moisture condenses, releasing energy of latent heat of condensation. This extra heating raises summer land – ocean pressure differences higher than in the absence of moisture in the atmosphere. Moisture processes therefore add to the vigour of the monsoon.

iii. The earth's rotation. This rotation produces a rotation force called the Coriolis force. In northern hemisphere the Coriolis force bends the monsoon current to right–hand, and it bends to the left–hand in southern hemisphere. The Coriolis force cause the monsoon currents moves in curved paths. Inter – hemispheric differences in the direction of the Coriolis force also cause winds to change direction as they cross the equator, see figure 7.



(a) (b)

Figure 7. East and South–East Asian Monsoon in northern hemisphere winter (a) and summer (b). Source : Susilo, 1996.

Among the monsoons, East and South–East monsons are well development due to its large of Asian Continent and the effect of highland Tibet as a barrier between polar and tropical air mass. In northern hemisphere winter, it is formed high pressure cell in northern Asian Continent centered in Siberia. In southern hemisphere winter air flow in the opposite direction, southeast wind come from high pressure cell or anticyclone over Australian Continent blows toward northwest passes Indonesia and Indian ocean.

Intertropical Convergence Zone

The air mass from the two hemisphere converges in a band called the Intertropical Convergence zone (ICZ). This ICZ is located in the equatorial low pressure area as a claudy and weak wind, it is called as **doldrums**. This convergence zone has various different name due to different perception about the structure and characteristic of this convergence zone. Besides Intertropical Convergence Zone (ICZ), there are the other name, such as Intertropical Front (IF), Equatorial Front (EF), and Intertropical Discontinuity (ID).

Because of air masses from the two hemispheres have the equal thermal characteristics, the name of front is less known in the tropic. The application of the word front i.e., Intertropical Front and Equatorial Front is therefore not exactly the same. In general, the Intertropical Convergence Zone (ICZ) is used over ocean, while the Intertropical Discontinuity (ID) is a fitname applied over continent. The structure and characteristics of ICZ and ID depend on the location, such as topography, distribution of continent and ocean. ICZ and ID displace toward north in boreal summer and toward south in austral summer following the annual migration of the sun. In July (boreal maximum summer) the position of ICZ/ID is about 25^0 N over Asia Continent, between 5 and 10^0 N over ocean. In January (austral maximum summer) the position of ICZ/ID is about 15^0 S over continent and near equator over ocean see Figure 8.

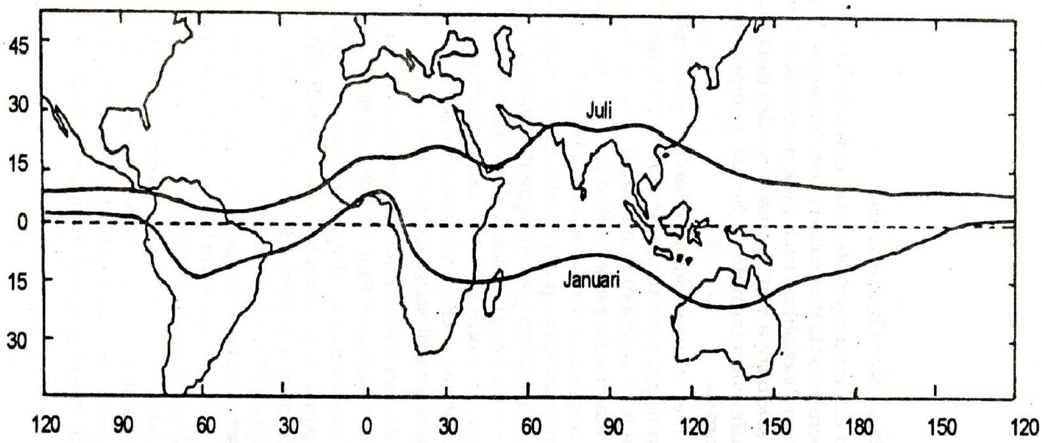


Figure 8. Mean position of ICZ in January and July.

The Walker Circulation and Dipole Equatorial Ocean

The Walker circulation is a zonal circulation along the equator. In normal condition it is characterized by the ascent of air in the western Pacific and descent in the eastern Pacific off the coast of Equatorial South America. This circulation is found by Sir Gilbert Walker who in the 1920s, had recognized an east to west variation of atmospheric pressure across the Pacific. This pressure see–saw Walker called the southern oscillation (SO). The intensity of the Walker circulation appears to be controlled by sea surface temperature variation in the eastern and western Pacific. Changes in sea surface temperatures are transferred into the atmospheric pressure changes. The increase sea surface temperature (SST) or warm episode in central and eastern Pacific called El Niño. The combination of ocean and atmospheric events have known as ENSO (El Niño – Southern Oscillation).

In the El Niño years, the Walker circulation subsides in the western Pacific and ascends in the central and eastern Pacific. On the Contrary, the non El Niño (La Niña), the Walker circulation ascends in the western Pacific and descends in the eastern Pacific. In the La Niña years occur strengthen of the convection in the western Pacific.

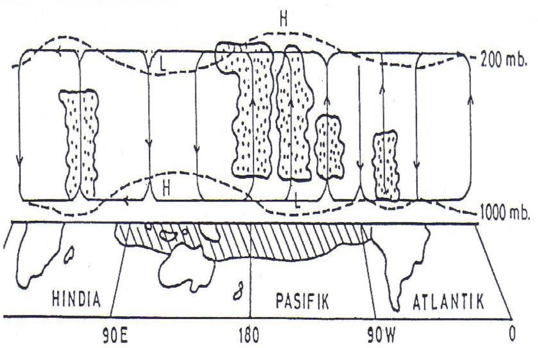


Figure 9a. Zonal equatorial circulation in the El Niño years.

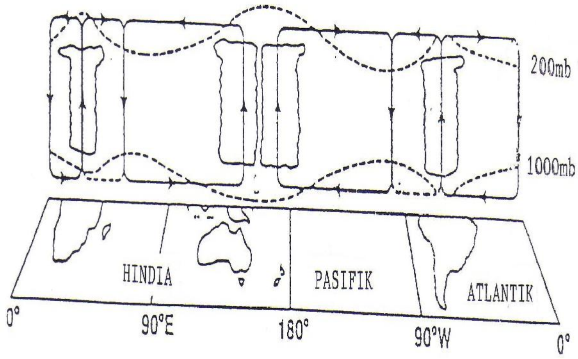


Figure 9b. Zonal equatorial circulation in the La Niña years.

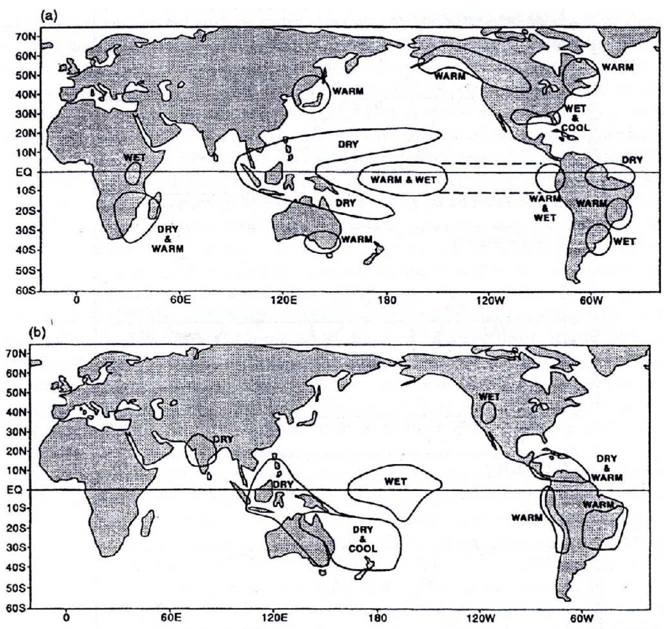


Figure 10. The Impact of El Niño events in (a) December to February, (b). June to August (Mc Gregor and Nieuwolt, 1998).

One of the most noticeable changes to weather patterns of the low latitudes during ENSO years is the shift of thunderstorm activity from the Indonesian area eastward into the central Pacific. This results is anomalously wet conditions for the central Pacific islands, whil for tropical Australia, New Guinea, Indonesia and Philippines, abnormally dry conditions prevail in both summer and winter seasons (Figure 10).

La Niña, also has associated with it climatic anomalies. There is a complete reversal of the ENSO climatic anomaly in La Niña years. During La Niña, the normal central Pacific dryness is worsened due to cooler than normal SST suppressing rainfall formation processes through their effect on atmospheric stability (Figure 11).

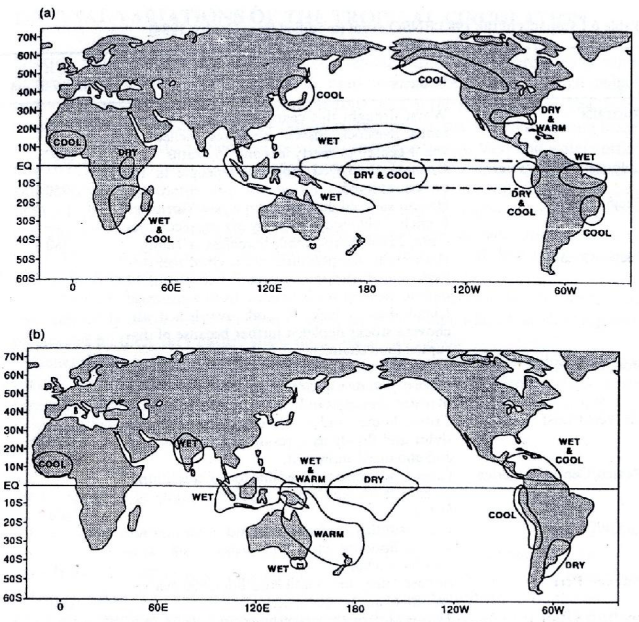


Figure 11. The impact of La Niña (the antithesis of El Niño) events for (a) December to February, (b) June to August (Mc Gregor and Nieuwolt, 1998)

Indian Ocean Dipole (IOD) or Dipole Mode (DM) is natural phenomenon which emerge from coupled interaction between atmosphere and ocean in the Indian Ocean. Rainfall in the western Sumatera in influenced by Dipole Mode in the equatorial Indian Ocean (Saji et al., 2001). IOD negative increase and IOD positif decrease the rainfall in West and South Sumatera. IOD or DM is determined by the fluctuation of SST above and below the normal between east coast of Africa and west coast of Sumatera. Dipole Mode Index (DMI) is determined by the difference of SST anomalies in the western (box A : 50^0 E – 70^0 E, 10^0 S – 10^0 N) and eastern Indian Ocean (box B : 90^0 E – 110^0 E, 10^0 S – 0^0 eq.), see Figure 12 and 13.

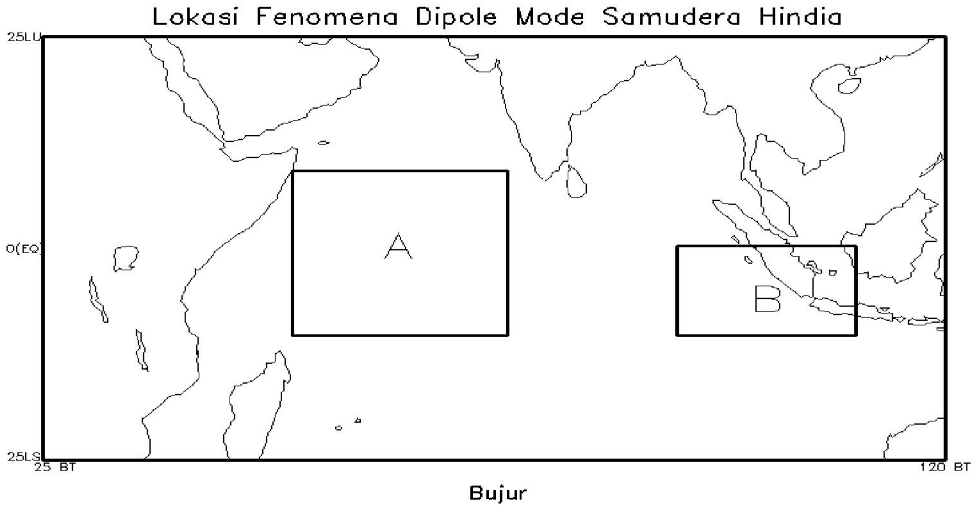


Figure 12. Determination of DM in the equatorial Indian Ocean.

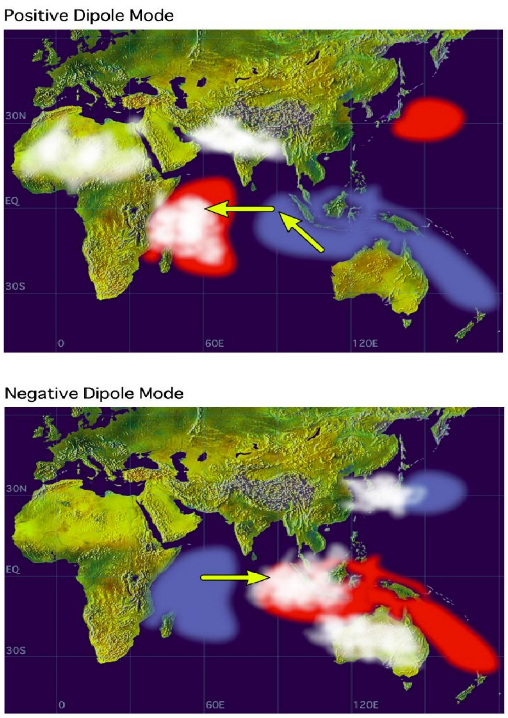


Figure 13. Positive and negative Dipole Mode.

Tabel 2. The average number of month that has rainfall amount less than 150 mm (1961 – 2000).

Rainfall Station	Fenomena El Nino, IOD (+)	Fenomena La Nina, IOD (–)
Western Indonesia		
Aceh	8,2	8,1
Padang	2,8	1,9
Medan	6,0	5,0
Jakarta	7,5	6,9
	6.1	5.5
Central Indonesia		
Banjarmasin	6,0	3,1
Pontianak	3,3	1,7
Pangkal Pinang	5,9	3,3
Madiun	7,1	6,1
	5.5	3.6
Eastern Indonesia		
Ujung Pandang	6,9	4,7
Manado	4,9	1,9
Sentani	7,0	6,9
Sorong	5,4	2,4
	6.0	4.0

The Character of Rainfall in the Monsoons

Heavy rain falls from thunderstorms. Figure 14 shows areal variation in the ratio of the average number of thunderstorm days to the average rainfall (dm) is small. The areal ratio ranges from 16 over western Africa and southeastern Tibet to leas than 2 over China, Southwestern India, and the ocean. There are two types of monsoon rain regime : the West African, in which frequency of thunderstorm days and rainfall increase to maxima in midsummer, and the western Indian in which frequency of thunderstorm days decreases as the rainfall increases.

The impression that frequency of thunderstorm days and rainfall are inversely related is reinforced by mesoscale studies in Southeast Asia. Summer vertical profiles of virtual equivalent potential temperature at Southeast Asian stations reveal greater convective instability on fine days than on wet days, see Figure 15.

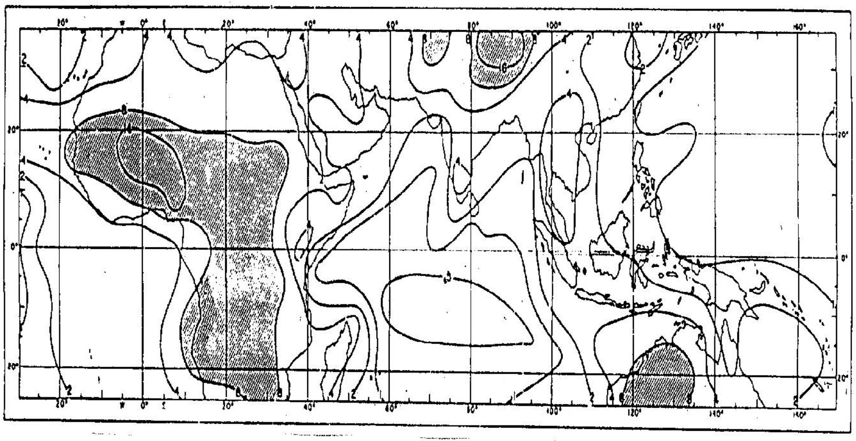


Figure 14. Ratio of the annual mean number of thunderstorm days to the mean annual rainfall in decimeters (from Portig in Ramage, 1971.)

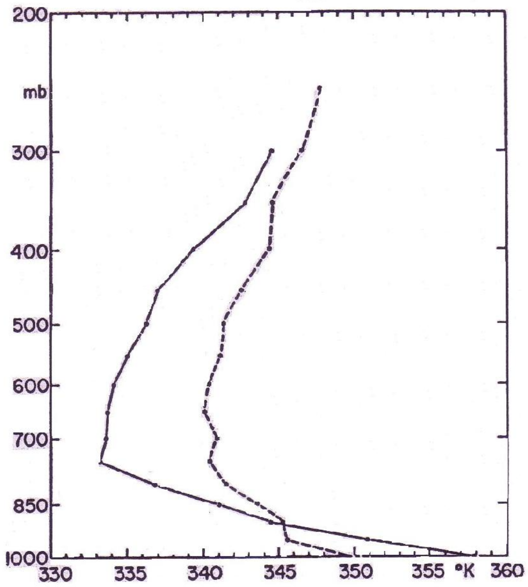


Figure 15. Vertical profiles of mean virtual equivalent potential temperature (θ_{ve}) at 12.00 UT (Universal Time) for Saigon during periods of good weather (full line) and bad weather (dashed line) during Jully 1996 (Harris et al., in Ramage, 1971).

Resumé

The solar energy per area unit that falls at the top of atmosphere before experiencing attenuation at a mean distance 150 x 10^6 km is called as the solar constant $\simeq$ 2.0 cal cm^{-2} mnt^{-1}. Actually, the solar constant varies depend on the uphelion and perihelion. Solar radiation is the main energy source for processes that operate in the climate system. Because the low latitudes receive more radiation than they lose, the surface net radiation balance is positive.

Monsoon wind is caused by the physical properties between ocean and continent. The ocean becomes warm slowly when there is solar radiation and it also becomes cool slowly when there is no sunlight compared to continent. As a result, the ocean is cooler in summer and it is warmer in winter compared to the continent. The monsoon are characterized by seasonal reversal of the prevailing wind systems and seasonal contrast in regimes of cloudiness, precipitation and temperature. Differential seasonal heating of oceans and continents, moisture processes in the atmosphere and the earth's rotation are the main factors which explain the existence of the monsoon.

The Indian Ocean Dipole (IOD) influence rainfall in the western Sumatera. IOD negative increase the rainfall, while IOD positive decrease the rainfall in West and South Sumatera. El Niño/IOD (+) cause the decrease and La Niña/IOD (–) event cause the increase of rainfall amount in Indonesia. Dipole Mode Index is determined by the difference of SST anomalies in the western and eastern Indian Ocean.

Acknowledgements

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