THE INDIAN SUMMER MONSOON CONTRIBUTION TO THE JJA RAINFALL OVER THE NOTHERN PART OF SUMATRA DURING THE CO-OCCURING EL NINO AND DIPOLE MODE (+) YEARS

SRI WORO B. HARIJONO[1]

Abstract

This article describes the further study investigating the JJA rainfall formation in the northern part of Sumatra during the co-occurring El Nino and Dipole Mode (+) years. Analyses based on wavelet transformation reveal that the rainfall in that part of Sumatra is insensitive or at least insignificantly influenced by El Nino and/or DM(+). This study confirms also that the Indian Summer Monsoon (IM) may play important roles in the rainfall budget of the region including in compensating the possible reduction effects of both El Nino and DM(+) on the JJA rainfall. The characteristics of JJA rainfall over the northern part of Sumatra on a wavelet time-frequency plane are descreibed, and the relative contributions of EN – DM – Indian summer monsoon in the rainfall over the northern part of Sumatra are demonstrated by using multicolinear statistical analysis

Key Words: Indian Summer Monsoon, Rainfall, El Nino, Dipole Mode

I. Introduction

The association of drought over the Maritime Continent of Indonesia and other part of the tropical west Pacific with the low phase of the Southern Oscillation and El Niño conditions in the Pacific has long been recognized (e.g., Walker and Bliss, 1932, Bjerknes, 1969). In particular, drought in the Maritime Continent region is explained in terms of remotely forced subsidence associated with an eastward shift of convection towards the central Pacific. This inverse relationship of Indonesian rainfall with El Niño is only strong during the dry season (e.g., Ropelewski and Halpert, 1987). Among the other factors that may drive rainfall variability across the Maritime Continent, the effect of Indian Ocean Dipole Mode (IODM or DM) has received considerable attention. This SST variations in the tropical Indian Ocean, which have been postulated to occur independently of El Niño, have also been linked to rainfall variations across Indonesia (e.g., Saji *et al.*, 1999), as such the decrease of rainfall in some parts of Indonesia, mainly in the western part, is interpreted to result from an eastward shift of convection into the central and western part of Indian Ocean and weakening of the zonal circulation in the Indian Ocean. The general conclusions concerning the impacts of El Nino and DM on the Indonesian region mentioned above should, however, be intrepreted catiously since there is strong observational evidence indicating that some regions, e.g. the northern part of Sumatra, may not significantly be influenced by those phenomena (Harijono, 2005).

[1] Meteorological and Geophysical Agency (BMG)

This study will further extend the previous preliminary results by the author (Harijono, 2005) in investigating the JJA rainfall formation in the northern part of Sumatra during the co-occurring El Nino and DM(+) years. It was shown that the rainfall in that part of Sumatra is insensitive or at least insignificantly influenced by El Nino and/or DM(+). In the same article, it was conjectured that the Indian Summer Monsoon (IM) may play important roles in the rainfall budget of the region including in compensating the possible reduction effects of both El Nino and DM(+) on the JJA rainfall. Figure 1 shows some important characteristics related to the Indian Summer Monsoon. The main objectives of this study are, firstly, to study the characteristics of JJA rainfall over the northern part of Sumatra on a wavelet time-frequency plane and, secondly, to demonstrate the relative contributions of EN – DM – Indian summer monsoon in the rainfall over the northern part of Sumatra, by employing multicolinear statistical analysis.

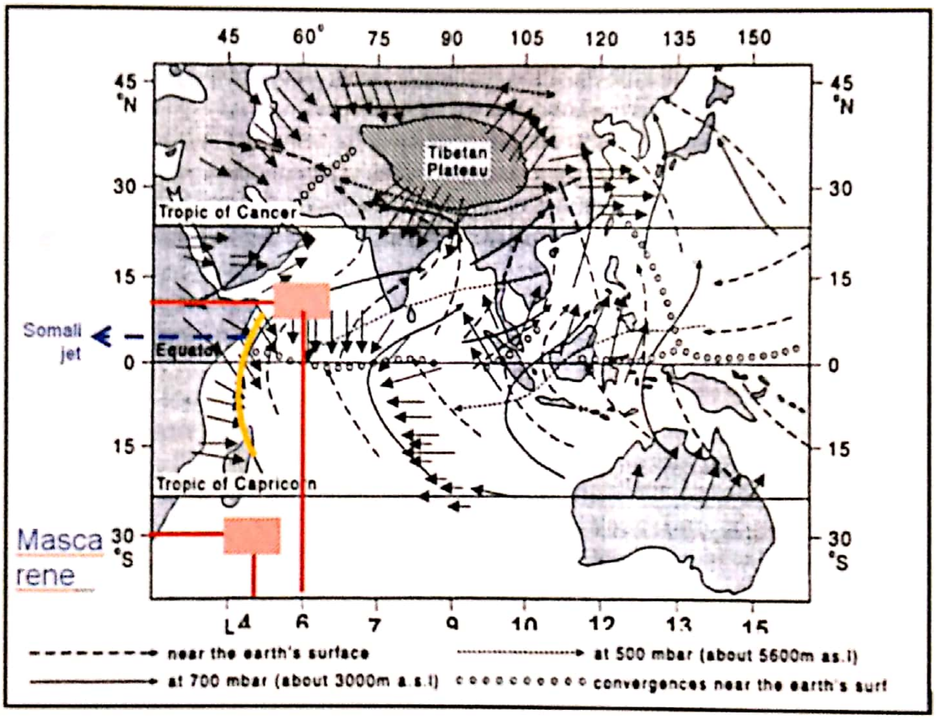

Fig. 1. Main characteristics related to the Indian Summer Monsoon.

II. Material and Method

The analysis is based on the following types of data: station rainfall, ENSO, IODM, and Indian monsoon indices. All types consist of monthly means, in order to eliminate the strong shorter period variability. NCEP reanalysis wind and precipitation data (1950-2000) is used to study the characteristics of air mass circulation. The rainfall data is used to derive the multicolinear regression equation. EN, DM, and IM indices are used as inputs to derive multicolinear regression equation as well as inputs to run wavelet transformation to examine the connection between time frequency, characteristics of rainfall with those of EN and DM. For Indian summer monsoon we use all Indian rainfall as an index.

The availability of water vapor mass as well as zonal and meridional circulation/ ascending motion toward the northern part of Sumatra, are described on the basis of NCEP model re-analysis data and displayed using GrADS (Figures 2 and 3).

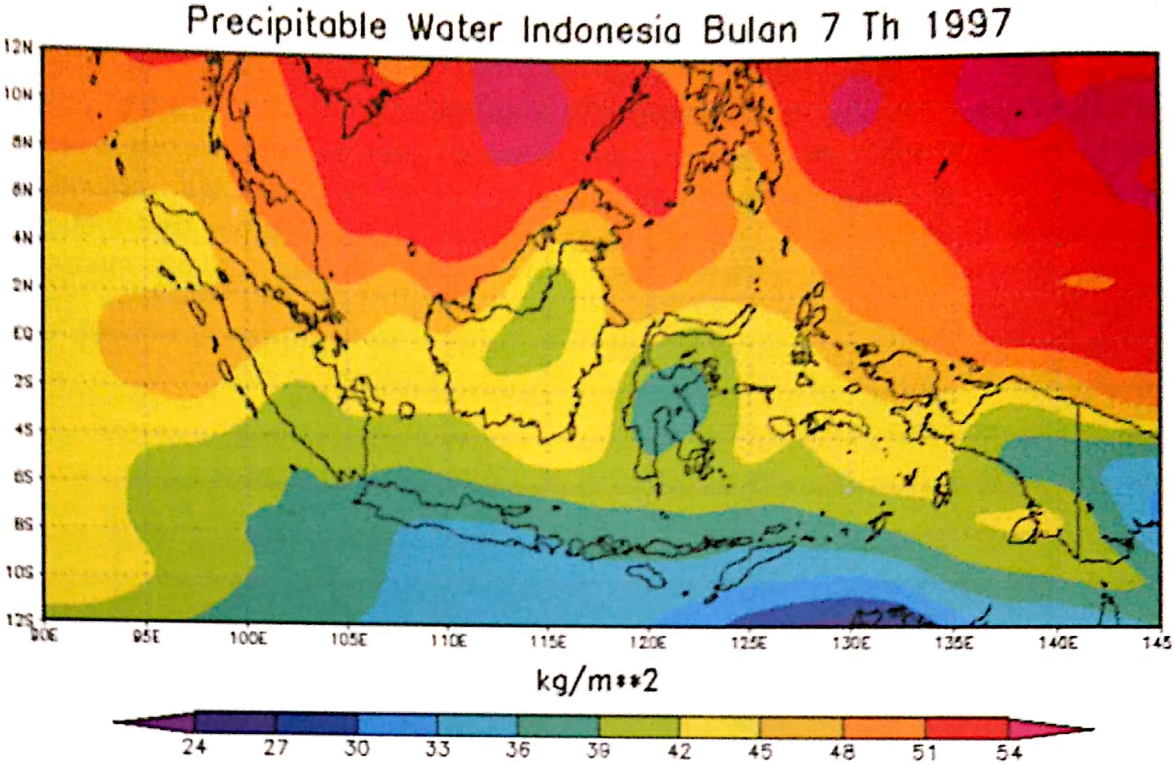

Fig. 2. Precipitable water and cloud cover in July 1997

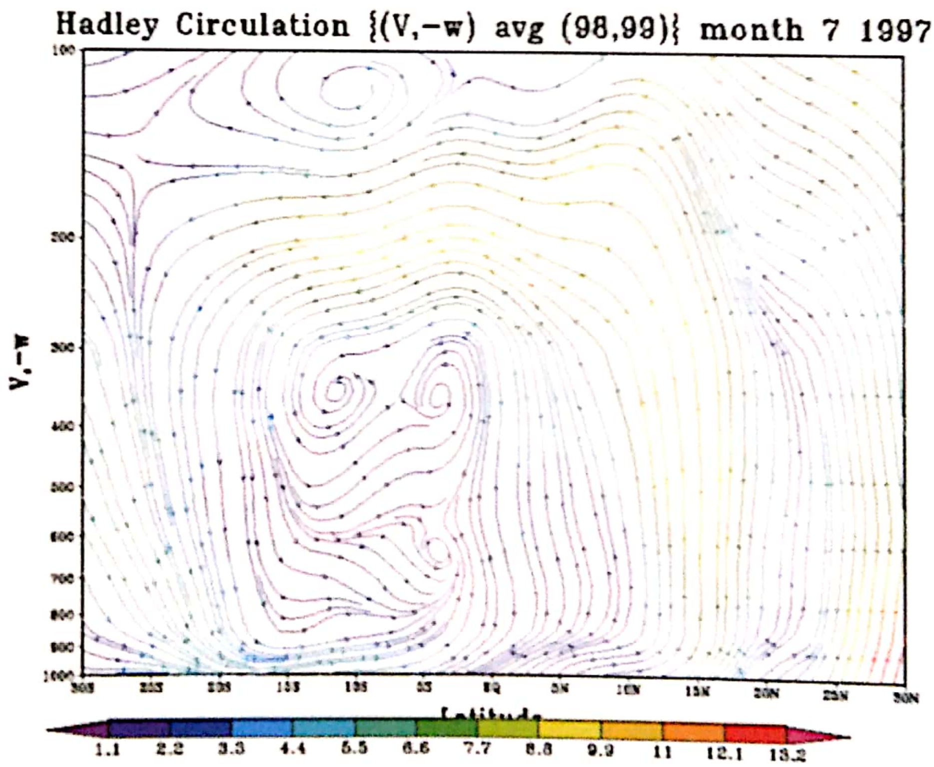

Fig. 3. Meridional (Hadley) circulation for Medan (upper panel) and Aceh (lower panel)

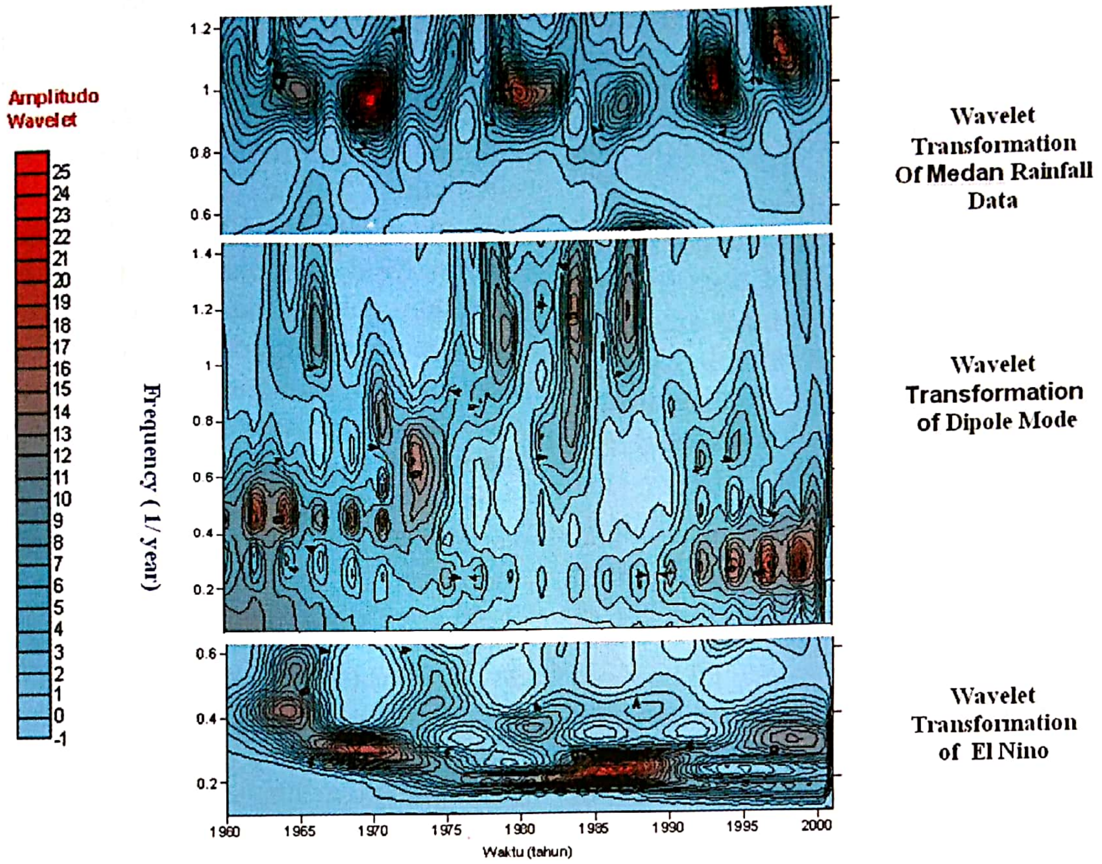

Fig. 4. The wavelet transformation of the Medan rainfall, ENSO and IODM timeseries

The wavelet transformation of the rainfall, ENSO and IODM timeseries are displayed in Figure 4. Results of wavelet transformation showing that prominent amplitude of both EN and DM phenomena in their specific frequencies are not in accordance with those of rainfall in the Northern part of Sumatra specifically Aceh and Medan. This is to show that EN and DM events insignificantly influence the rainfall reduction in the said region.

The contribution levels of of EN, DM and Indian Summer Monsoon to the rainfall budget over the northern part of Sumatra (e.g., Medan, Aceh) are examined by employing multicolinier statistical analysis.

III. Results and Discussion

From the figure describing the precipitable water and cloud cover distribution as well as wind direction prepared using GrADS based on NCEP Reanalysis Data (Figure 4), it is shown that:

- Water vapor mass in the surrounding region (northern part of Sumatra) on JJA is available
- Zonal circulation clearly shows ascending motion toward the northern part of Sumatra.

One of the main advantages of wavalet transformation is that it can provide us with detailed information on change of amplitude and frequency as a function of time. In the case of this study, the results of wavelet transformation showing that prominent amplitude of both EN and DM (+) indices in the specific frequency are not in accordance with those of rainfall in the northern part of Sumatra, specifically Aceh and Medan.

It is clearly indicated that strong amplitude of rainfall occur in the periode of one year while those of E.N occur in the periode of 2½ year and prominent amplitudo of DM (+) occur in the periode of 2 – 4 year.

Wavelet transformation demonstrated that prominent amplitude of both EN and DM in their specific frequencies are not in accordance with those of rainfall. That is to say, EN and DM event an-insignificant impact on rainfall distribution over the area of study.

The relative contribution of EN and DM as well as air circulation on rainfall raise, examined from the output of multicolinier statistic model:

- Both EN – DM tend to reduce the rainfall albeit just in insignificant amount (<15%). This result is in confirmation with those examined by wavelet transformation.
- For Medan: EN – DM contribute respectively 2.5 % and 5.5% reduction of rainfall Indian summer monsoon provide 6.1% increase of rainfall.
- For the northern part of Sumatra, EN - DM contribute respectively 1.8% and 9.9% reduction of rainfall while Indian monsoon provide 5.1% increase of rainfall.

Large variations do exist among the results for individual concurrent EN-DM year. However, in general, we may conclude that for the northern part of Sumatra the influences of EN and DM are both insignificant. Their effects are compensated by the rainfall increase induced by processes related to the Indian summer monsoon.

The mechanism that cause rainfall raise over the northern part of Sumatra associated with Indian Summer Monsoon circulation, EN, DM events that can be described as follows.

Equatorial atmospheric dynamics over the Indonesia - Maritime continent is strongly influenced by the zonal (Walker) circulation and meridional (Hadley) circulation, in addition to other local circulations. The zonal circulations is closely related to EN and DM events, while local circulations play highly important role in the convection process, function as the major mechanism for the tropical rain formation. The meridional one is associated with the lateral monsoons, in particular the Indian and the Asia – Australia monsoons. The rainfall variability in the maitime cantinent Indonesia is very much determined by these three kinds of circulation.

In the normal years (without EN and DM), the Indian Summer monsoon circulation involving a number of dynamic structural elements, among others: The monsoon trough over northern India – the Mascarene anticyclone system - the low level cross equatorial jet – the Tibetan high pressure system - the tropical easterly jet – Monsoon Cloudiness.

As shown in the Figure 1, The monsoon trough, formed over nothern India is part of global ITCZ. South-westerly wind to the south of the trough and easterly wind to the north, formed a zone of surface low pressure. Over the south east Indian ocean (30°S, 50°E) there exist a large outflow of air (known as the Mascarane anticyclone system) move north over cross the equatorial East African become a south-westerly flow (known as Somali Jet).

In its maximum intensity (JJA) the Somali Jet will split into two direction (in 10°N - 60°E) across Arabian sea to south of Indian and arrive in the south of Indian Ocean and the west of Indian coast.

In JJA, low pressure areas in Indian continent lead to water mass transport from the Arabian Sea. Due to the blocking effect by the high pressure condition in Tibetan Plateau, the air flow is deflected to the south-eastward direction toward the northern part of Sumatra.

When EN and DM occur simultaneously, the air mass flow related to the intensification (cross equatorial Hadley circulation) originating from the new anomalous divergence center in the eastern Indian Ocean is deflected eastward when crossing the equatorial line toward the northern part of Sumatra.

In relation with the Indian Summer Monsoon, the stronger the Indian Monsoon, the more the additional water mass transported to the northern part of Sumatra. The pressure gradient between the persistent relatively colder and higher pressure region (in the Tibetan Plateau) and the lower pressure region (Indian continent and the Bay of Bengal) serve as a driving mechanism for the air mass transport. In both cases the uplifting/ ascending motion of water mass is facilitated by the surrounding topographical condition.

In June – July – August, low pressure area in Indian continent lead to water mass transportation from the Arabian Sea. Due to the blocking effect by the high pressure condition in Tibetan Plateau, the air flow is deflected to the south-eastward direction toward the northern part of Sumatra.

The Indian Summer Monsoon has large contributions on the processes of air mass transportation and uplifting, triggering cloud formation leading to compensating or neutralizing the EN – DM rainfall deficit.

IV. Summary and Conclusions

We have discussed the results of further study investigating the JJA rainfall formation in the northern part of Sumatra during the co-occurring El Nino and DM(+) years. Analyses based on wavelet transformation indicate that the rainfall in that part of Sumatra is insensitive or at least insignificantly influenced by El Nino and/or DM(+). This study confirms also that the Indian Summer Monsoon (IM) may play important roles in the rainfall budget of the region including in compensating the possible reduction effects of both El Nino and DM(+) on the JJA rainfall. The characteristics of JJA rainfall over the northern part of Sumatra on a wavelet time-frequency plane are described, and the relative contributions of EN – DM – Indian summer monsoon in the rainfall over the northern part of Sumatra are demonstrated by using multicolinear statistical analysis. It is found that both EN – DM tend to reduce the rainfall albeit just in insignificant amount (<15%). This result is in confirmation with those examined by wavelet transformation. In the case of Medan, EN and DM contribute respectively 2.5% and 5.5% reduction of rainfall Indian summer monsoon provide 6.1% increase of rainfall. Similarly, for the northern part of Sumatra, EN - DM contribute respectively 1.8% and 9.9% reduction of rainfall while Indian monsoon provide 5.1% increase of rainfall.

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