Research Paper

OBSERVED PRECIPITATION CHARACTERISTICS IN MJO PHASES OF VIET NAM

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ABSTRACT

The research uses synoptic station data and MJO index to analyse the precipitation distribution all over Viet Nam. The mean rainfall amount in the Northern region tends to increase in MJO phases 1 and 2; the rainfall anomalies in the North Central provinces are positive in phases 3, 4 and 5; from Middle Central to Southern provinces, MJO increases the rainfall, especially in phases 4 and 5. During transitional seasons (MAM and SON), positive rainfall anomalies in those wet phases tend to be higher than those in summer and winter, especially in SON.

Keywords: *Rainfall anomaly, MJO, wet phases.*

1. Introduction

The MJO is a tropical large-scale oscillation that is dominated by periods of 30-60 days and the zonal wave number one propagating eastward (Madden and Julian, 1971). It is the low frequency variation in the intensity of the wind in the upper atmosphere and the variation of temperature at different levels combined with the surface pressure. The longest oscillation period is at about 41-53 days and has the largest frequency at about 45 days. The 40-50 day fluctuation is the basis for explaining some of the low frequency fluctuations of tropical circulation and climate fluctuations. Among these characteristics, the movement from west to east of the 40-50 day oscillation has the greatest significance. This movement is expressed as an atmospheric wave, most of which is related to the movement of intense convection. These convections move at speeds of 10-30 m/s from the Indian Ocean to the western Pacific Ocean and across the Pacific Ocean to South America. The surface effects of convection movement to the east can be seen in some equatorial regions suitable for temperature and surface pressure changes with a 40-50 day cycle.

In addition to the above-mentioned spatial characteristics, oscillations of 40-50 days also have varying characteristics over noticeable time. For example, the variation between seasons is reflected in the nature of this oscillation. Subseasonal variation, including 10-20 days, 30-50 days and a week fluctuations (Ding, 1994) is the most important because this oscillation has major implications for the active and inactive phases of the monsoon. The oscillation has its own intensity variation with the weakest in the Western Pacific and the strongest in the Indian Ocean. The figure below gives an example of phase space diagram (Wheeler and Hendron,

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2004) of MJO representing position (areas from 1 to 8) and intensity (distance to the center of simplicity map) of MJO. Based on the two characteristics RMM1 and RMM2 in phase space, we will determine the current MJO location and intensity.

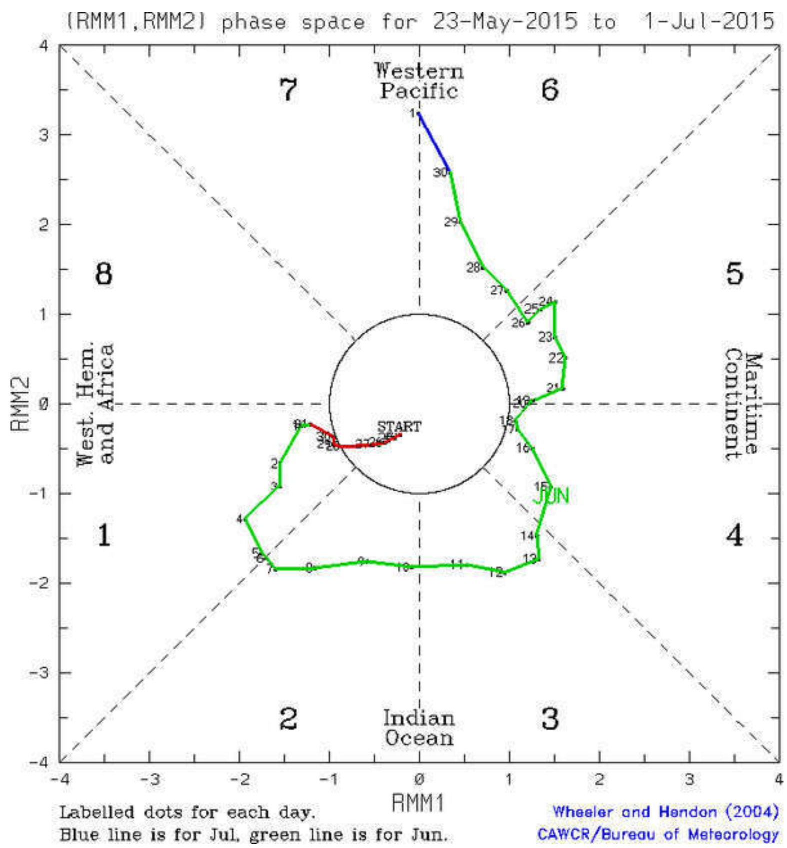

Fig. 1. Schematic representation of phase space of MJO with values of two characteristics RMM1 (horizontal axis) and RMM2 (vertical axis), global ocean areas (represented by numbers from 1 to 8) in which the Western Pacific region are two regions 6 and 7. Colors represent the months (red-May, Green - June and Blue - July).

Donald et al. (2006) evaluated the effect of the MJO on global-scale rainfall and found that MJO is an important phenomenon that may affect the daily rainfall distribution, even in high latitudes, through teleconection to large-scale sea level atmospheric pressure. Donald et al. (2006) also emphasized that MJO could be the mechanism and a predictor to bridge the weather forecast (usually only within the 5-day limit) and climate forecast (often highly skilled in 3-6 month forecasts). Through the composite of anomalies in the summer of the Northern Hemisphere in different MJO phases (2, 4, 6, and 8), there is a close relationship between the positive anomalies of precipitation and negative anomalies of mean sea level pressure and vice versa.

The MJO has a direct impact on the weather in the tropical region, as it organizes convection and precipitation. There have been many studies on the impact of the MJO on the South and East Asian (EA) region. Most of them, however, are for the boreal summer season (Zhu et al., 2003a, 2003b; Zhan et al., 2006). In summer, the MJO related intraseasonal disturbances tend to propagate northeastward that significantly influence the "active" and "break" monsoon rainfall fluctuations (Yasunari, 1979; Murakami et al., 1984; Wang et al., 2006). The disturbances associated with the MJO directly modulate the rainfall over the Asian continent through its influence on the genesis of higher frequency monsoon lows and depressions. As revealed by Goswami et al. (2003), a majority of such monsoon lows and depressions develop during the wet phase of the MJO. A recent study of Zhang et al. (2009) reported a significant impact of the MJO on summer rainfall in southeast China. The impact of the MJO on wintertime weather in East Asia, especially in its midlatitude region, is less well documented.

2. Data and method

The present study is based primarily on two data sources: observation rainfall data from 59 synoptic stations along Viet Nam that was provided by the National Centre for Hydro-Meteorological Forecasting, Viet Nam.

To identify phases of the MJO, we use the real-time multivariate MJO (RMM) index of Wheeler and Hendon (2004), which was downloaded from the Australian Bureau of Meteorology and is currently available from http://www.bom.gov.au/climate/mjo. All data collected from 1997 to 2015.

To analyse the characteristic of Viet Nam's precipitation in MJO phases, we extract days which is the same MJO phases to calculate anomaly of precipitation for 59 synoptic stations. For instance, rainfall anomaly of MJO phase 1 in January will be calculated by rainfall average of phase 1 minus rainfall average in January. Other phase anomalies are calculated similarly as above.

3. Characteristic of precipitation in Viet Nam in MJO phases

3.1. Characteristic of precipitation in MJO phase

Before examining the details of rainfall distribution in each MJO phase in each month, we analyzed the average rainfall characteristics in each phase in climate regions. Daily rainfall of 59 synoptic stations will be averaged for each phase in the period from 1997-2015. In which, it is divided into 3 main areas: Northern region; Central region and Central Highlands - Southern regions.

Fig. 2 shows the average rainfall in each phase in the Northern region. The graph shows that the daily mean rainfall in the Northern region is slightly different between phases, about 3-5mm/day, except for those stations have higher daily mean rainfall in most phases such as Lai Chau, Hoa Binh (Tay Bac), Sa Pa, Ha Giang (Viet Bac), Thai Nguyen, Tien Yen (Dong Bac).

It can be recognized that, the daily mean rainfall in phase 1 and phase 2 tends to be higher than other phases; additionally, in the delta region, the rainfall in phase 4 is also higher. The MJO is likely to increase rainfall in the Northern provinces in phase 1, phase 2 and in the delta region in phase 4.

In the Central region (Fig. 3), the difference in daily mean rainfall between phases is higher. The North Central provinces have the highest daily mean rainfall in phase 3, phase 4, phase 5 of which phase 4 is highest; Central and South Central provinces are phase 4, phase 5 (phase 5 is highest). There are also a number of stations that recorded remarkable rainfall in most phases such as Ky Anh, Hue, Quang Ngai, Quy Nhon and Truong Sa.

The Central Highlands-Southern region is the most southern region of Vietnam, the daily mean rainfall in this region is strongly modulated by the MJO, especially in the phase 5 and phase 4, especially at stations like Phu Quoc, Ca Mau and Pleiku (Fig. 3).

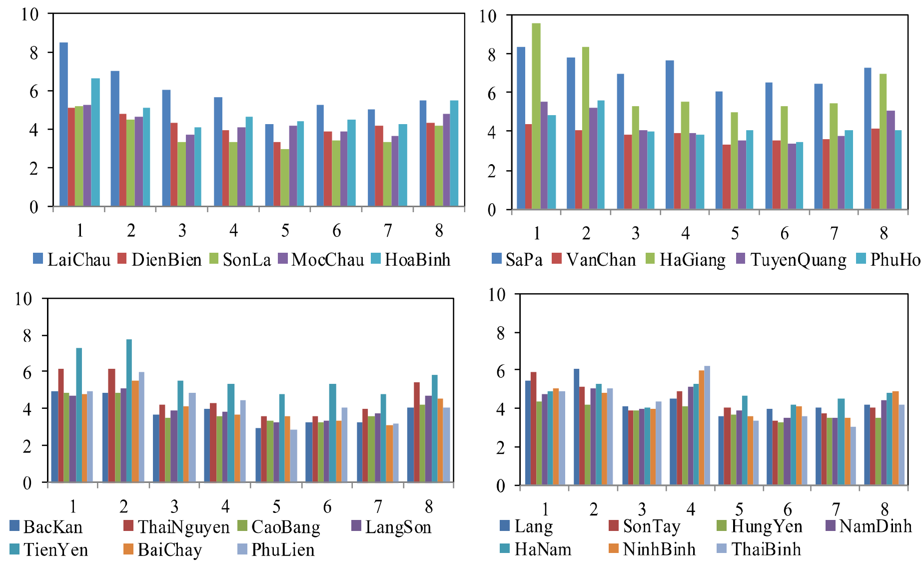

Fig. 2. The mean rainfall in each phase of the Northern region (Y axis is the daily mean rainfall; X axis is the MJO phases).

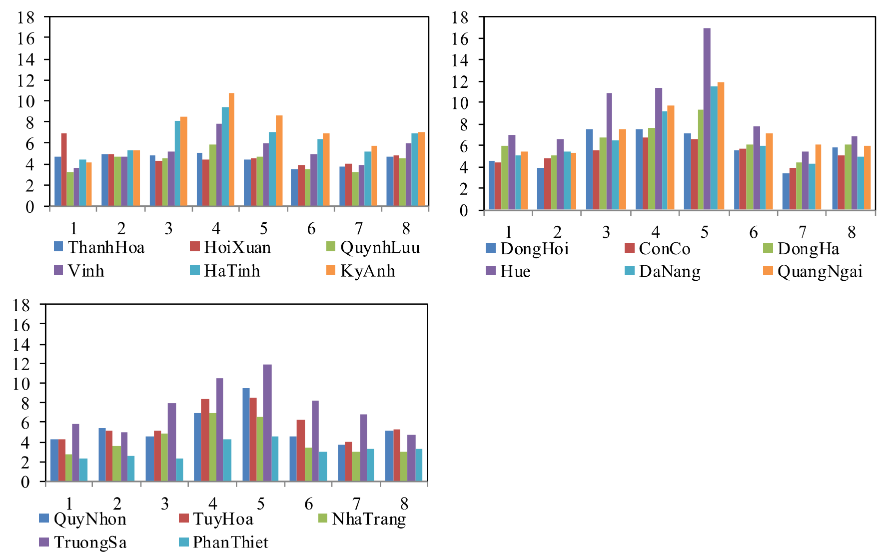

Fig. 3. The mean rainfall in each phase of the Central region (Y axis is the daily mean rainfall; X axis is the MJO phases).

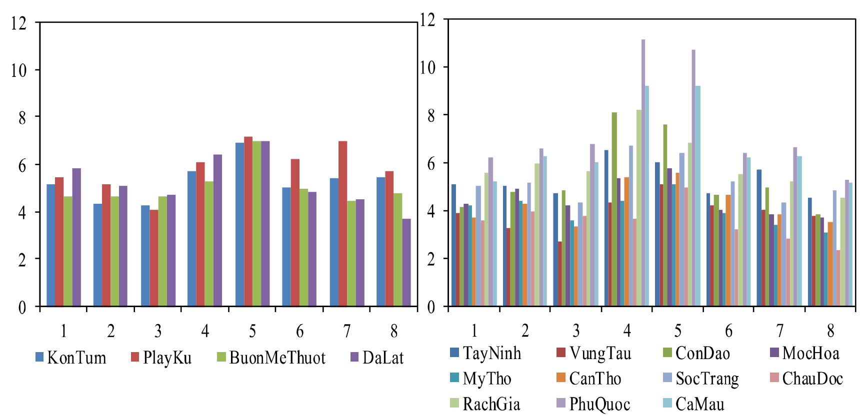

Fig. 4. The mean rainfall in each phase of the Central Highland- Southern region (Y axis is the daily mean rainfall; X axis is the MJO phases).).

By analyzing the daily mean rainfall distribution characteristics in each MJO phase, the higher daily mean rainfall is concentrated in phases 1 and 2 in the Northern region, phase 3, 4 and 5 in the Central region and Central Highlands - Southern provinces. However, the difference in rainfall between highest and lowest phases is not much.

In the next section, we will investigate the characteristics of rainfall distribution in each month by calculating the phased rainfall anomaly (i.e average rainfall minus monthly average rainfall in the period from 1997-2015). From the above characteristics, in the analysis of rainfall characteristics in each month, we will mostly focus on considering phase-averaged rainfall anomaly in phases 1, 2, 3, 4, 5 and some phases which have mean rainfall is higher than monthly mean rainfall.

3.2. Characteristic of precipitation in summers

In summer season (JJA), large-scale systems that have major impacts on Vietnam's weather are subtropical high pressure, Intertropical Convergence Zone (ITCZ), hot and dry low-pressure-area, tropical cyclones in the north and the southwest monsoon in the southern provinces. In this study, we analyzed the relationship between the MJO and the distribution of rainfall in Vietnam through rain characteristics in the MJO phases.

The observed rainfall anomalies in June and August in most of the stations are negative the phase 1 of the MJO, whereas in July, the observed anomaly are positive in the Northern provinces and negative elsewhere.

In phase 2, rainfall anomalies tend to be positive in the coastal stations of the Northern region in June and August. In July, rainfall anomaly is slightly positive in the north of Central provinces Vietnam. The southern provinces still maintain lower rainfall than the corresponding monthly mean rainfall (Fig. 5).

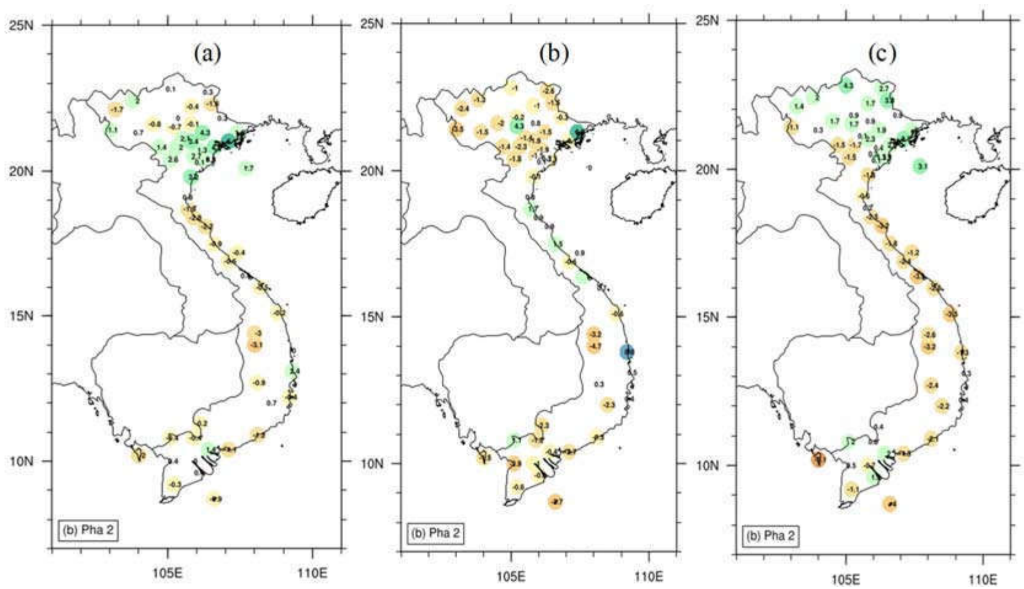

Fig. 5. The rainfall anomaly of phase 2 in Viet Nam in summer months (JJA), including: (a) June, (b) July and (c) August.

In June and August, positive rainfall anomalies in phase 3 are higher and expand further south (Fig. 6). In June, positive rain anomaly area is concentrated in the mountainous and highland areas of the North and Center of the Central provinces (from Quang Tri to around Quang Ngai). By August, rainfall anomaly has increased, especially in the northeast provinces of Northern Vietnam, then extended to the Mid-Central provinces. Rainfall anomaly in phase 3 is almost the same as phase 2 in July.

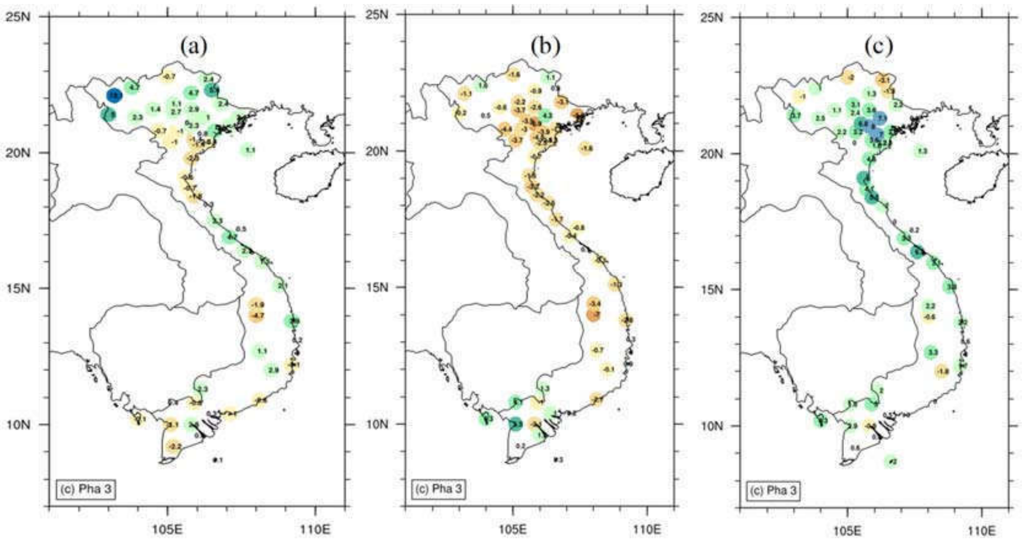

Fig. 6. The rainfall anomaly of phase 3 in Viet Nam in JJA months, including: (a) June, (b) July and (c) August.

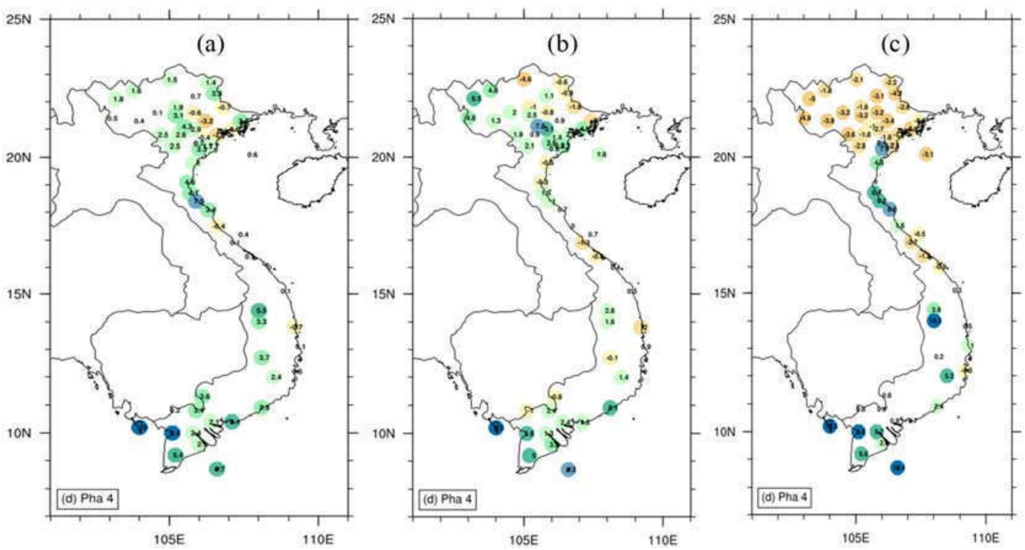

Fig. 7. The rainfall anomaly of phase 4 in Viet Nam in JJA months, including: (a) June, (b) July and (c) August.

The rainfall anomalies in phase 4 of June and July are clearly above normal for most of the stations in Vietnam, especially for the southern stations. However, in August, the rainfall anomaly Northern provinces shifted to negative, whereas the positive observed rainfall anomalies remained in the north central and southern provinces (Fig. 7).

The rainfall anomaly in phase 5 (Fig. 8) has increased rapidly in August, especially in the Mid-Central provinces. Meanwhile, in June and July, the rainfall anomaly in this phase decreased gradually in the Northern provinces, of which many stations turned to negative anomaly compared to phase 4. The positive rainfall anomaly in the southern provinces also tends to decrease slightly but still be positive.

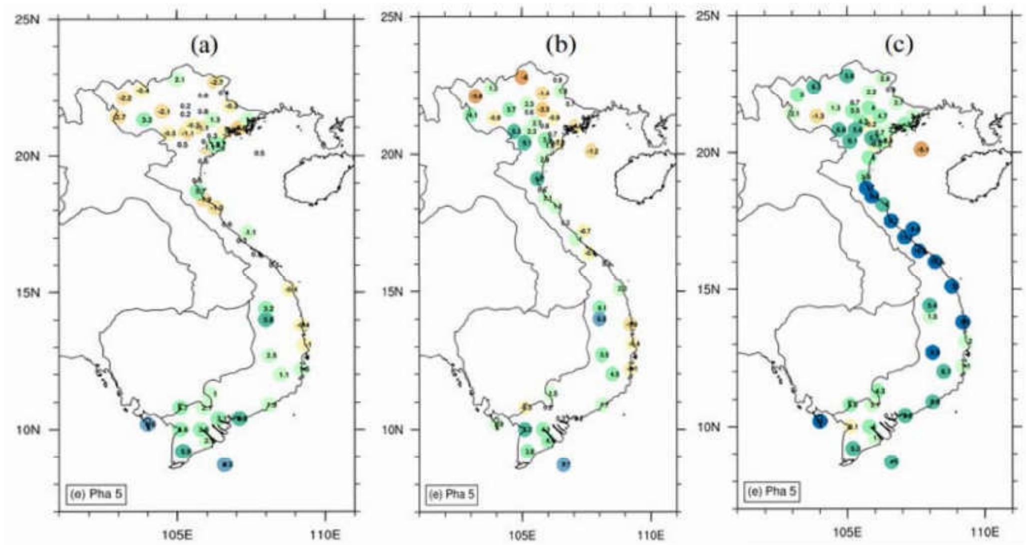

Fig. 8. The rainfall anomaly of phase 5 in Viet Nam in JJA months, including: (a) June, (b) July and (c) August.

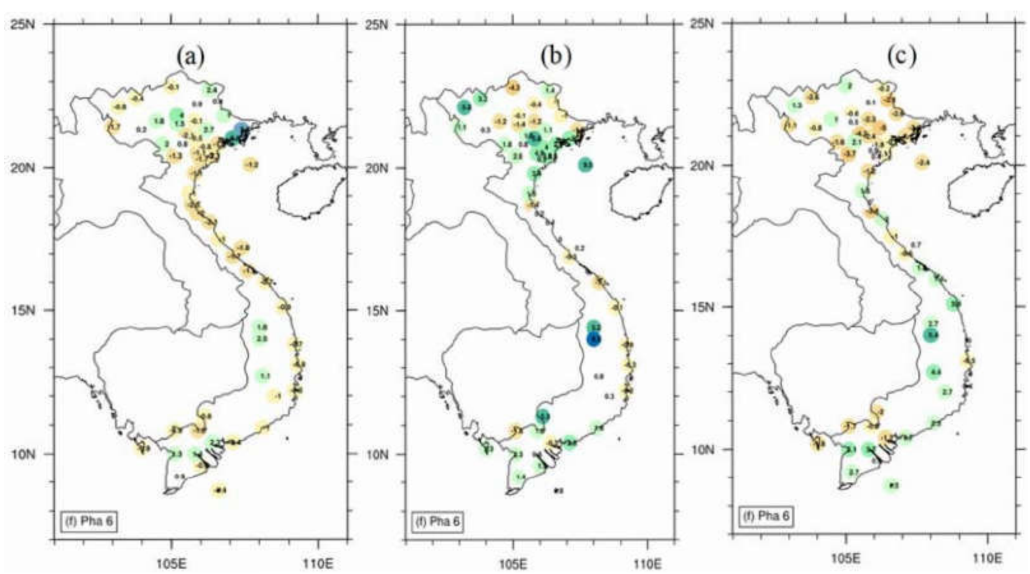

Fig. 9. The rainfall anomaly of phase 6 in Viet Nam in JJA months, including: (a) June, (b) July and (c) August.

In phase 6 (Fig. 9), the mean rainfall decreased rapidly in JJA months, in which August had the most decrease compared to previous phase 4 and 5. This decrease trend of the rainfall anomaly continues in phase 7 and 8 resulting the wide-spread negative rainfall anomaly in phase 7 all over Vietnam. The exception was observed in phase 8 rainfall anomaly in August with the dipole pattern of positive rainfall anomaly in the north and negative anomaly in the south.

The analysis of rain distribution in each MJO phase in the JJA shows that: in phase 4 and phase 5, the rainfall anomaly tends to be higher than monthly mean rainfall mostly all over Vietnam, with maximum positive anomaly in the Mid-Central, South-Central, Highlands and Southern provinces. In addition, in phase 3 and phase 6, in the Northern provinces, the near or above normal mean rainfall are also observed. Phase 1 and phase 7 in summer months are dry phase and phase 8 shows a dipole pattern of rainfall anomaly along Vietnam.

3.3. Characteristic of precipitation in Winters

In DJF months, the large-scale systems controlling Vietnamese weather are mainly cold surge, upper westerly jet stream in the north or equatorial trough and subtropical high in the south. Therefore, the activity of MJO could be one of the factors directly or indirectly associated with these large-scale systems and affecting the weather including the rainfall distribution in Vietnam during this time.

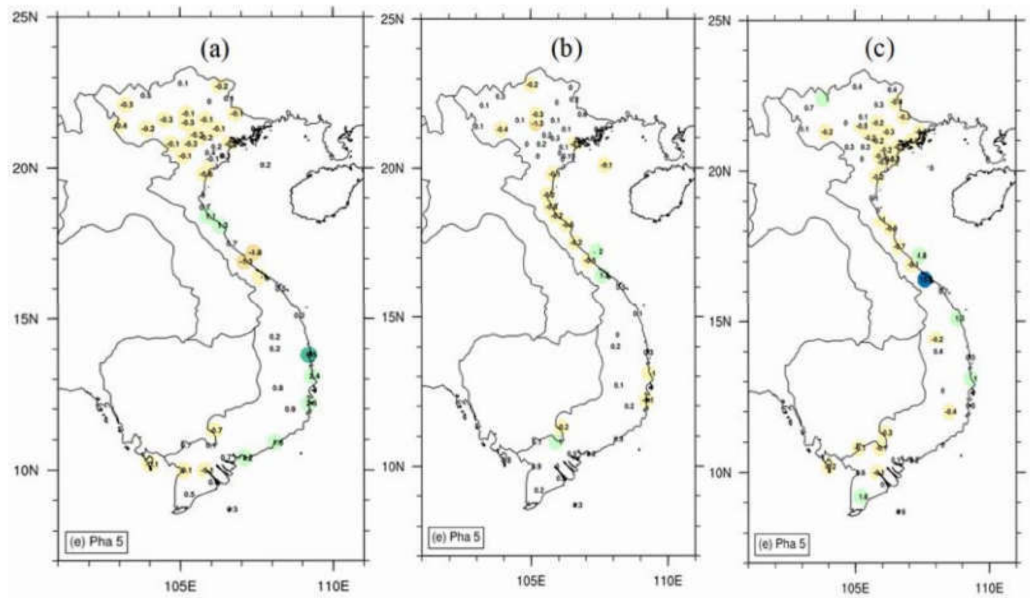

Fig. 10. The rainfall anomaly of phase 4 in Viet Nam in DJF months, including: (a) December, (b) January and (c) February.

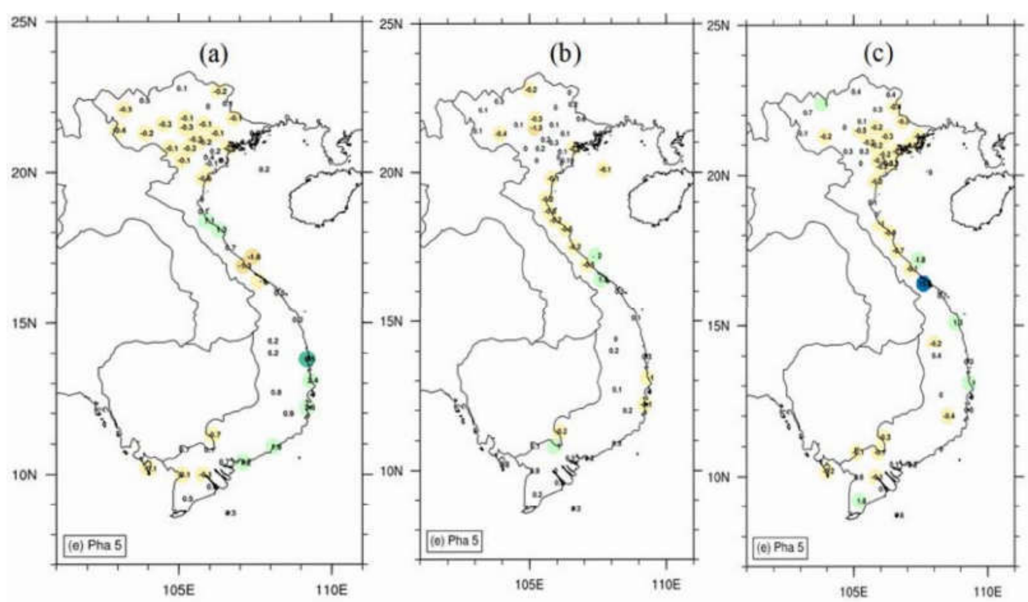

Fig. 11. The rainfall anomaly of phase 5 in Viet Nam in DJF months, including: (a) December, (b) January and (c) February

The rainfall anomalies in phase 4 are positive in December and February whereas the phase 4 rainfall anomaly in January is negative country-wide (Fig. 10).

During DJF, the positive rainfall anomaly in phase 5 is less than in JJA. The mean rainfall is only slight higher than normal in some coastal stations in the south-Central and Highlands in December and January. In February, most rainfall anomalies have negative values (Fig. 11).

Thus, in DJF months, the positive rainfall anomalies are often observed in phase 4, especially in December and February. In other phases, the rainfall anomalies are negative.

3.4. Characteristic of precipitation in transition period

During transition months, the dominate large-scale weather systems in Vietnam tend to weaken or dispute each other so the weather forecast in general and rainfall in particular is extremely difficult, especially in medium, extended range forecasts and beyond. Considering the characteristics of rain distribution in MJO phases of transition months is also one of the important factors to help forecasters have more reference tools before making a final official forecast.

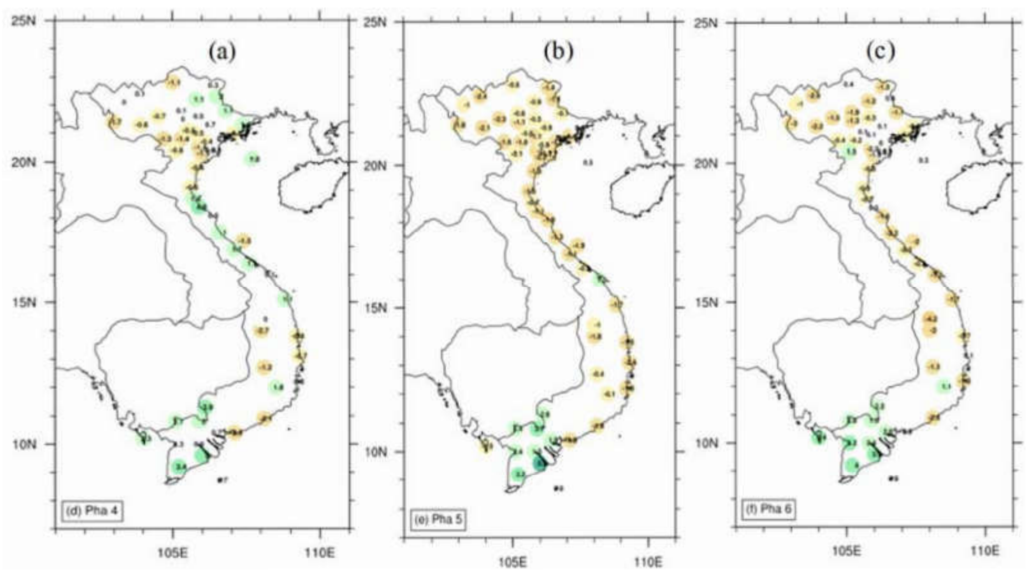

Fig. 12. The rainfall anomaly of April in Viet Nam in DJF months, including: (a) Phase 4, (b) Phase 5 and (c) Phase 6

In April (Fig. 12), the observed rain anomalies in the phases 4, 5 and 6 shows positive values in the Southern region. Therefore, it can be seen that the activity of MJO during this period also partly affects the rainfall distribution in the Southern provinces where as negative elsewhere in Vietnam.

Phase 7 of the MJO in April and May cause the mean rainfall anomaly (Figs. 13a-13b) to be positive most of Vietnam, except for some stations in the west of the Southern region in April and in the North of Vietnam in May.

Considering the transition period from summer to winter, including September, October and November. Fig. 14 shows that the positive rainfall anomalies appear more frequently during this period. The mean rainfall in phase 4, phase 5, phase 6 tend to be higher than corresponding monthly mean rainfall. In phase 4 (Fig. 14), positive rain anomalies focus mainly on the provinces from the south of the Northern Delta to the Highlands -Southern in September, October. In November, the positive rainfall anomalies continued to cover all Northern provinces; In addition, the rainfall anomaly values also tends to be higher in the Central coast region. This shows that MJO is likely in increasing rainfall anomaly in phase 4 in Vietnam in general and in the Middle Central provinces in particular.

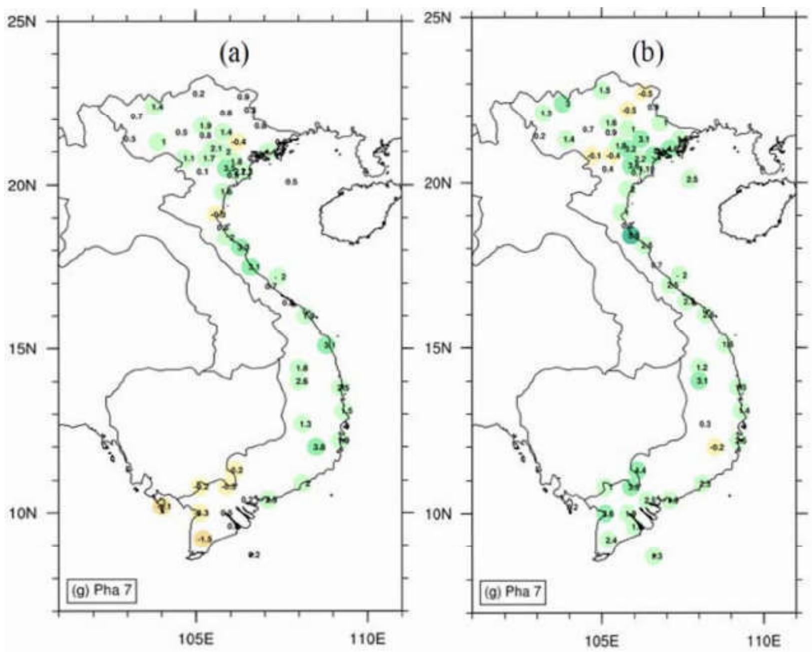

Fig. 13. The rainfall anomaly of phase 7 in Viet Nam in DJF months, including: (a) April, (b) May.

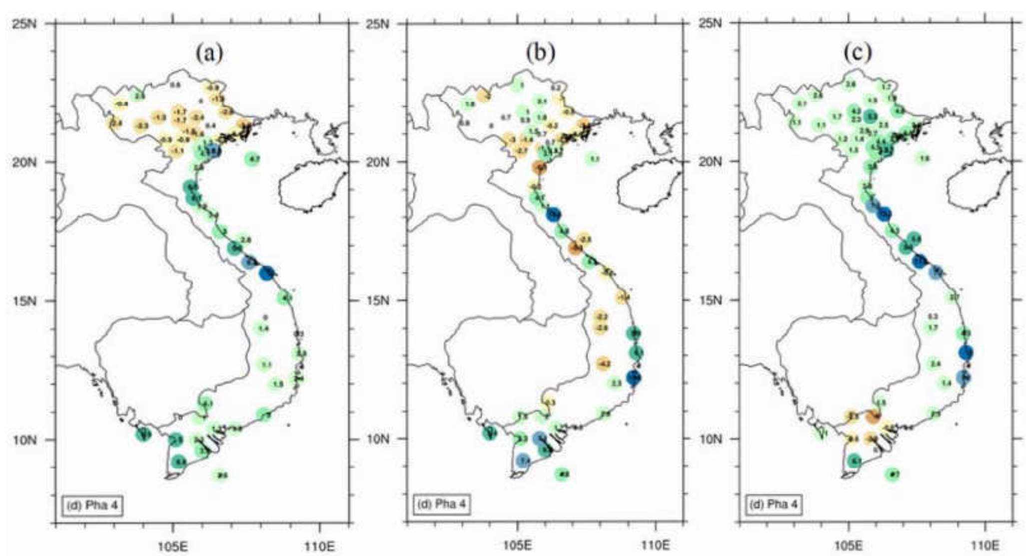

Fig. 14. The rainfall anomaly of phase 4 in Viet Nam in transition months, including: (a) September, (b) October and (c) November.

In phase 5 (Fig. 15), the positive rainfall anomalies are gradually narrowed to the south, concentrate on Central and Highland-Southern provinces. Specially, in November, it is still the highest positive rainfall anomaly in the Central coastal provinces.

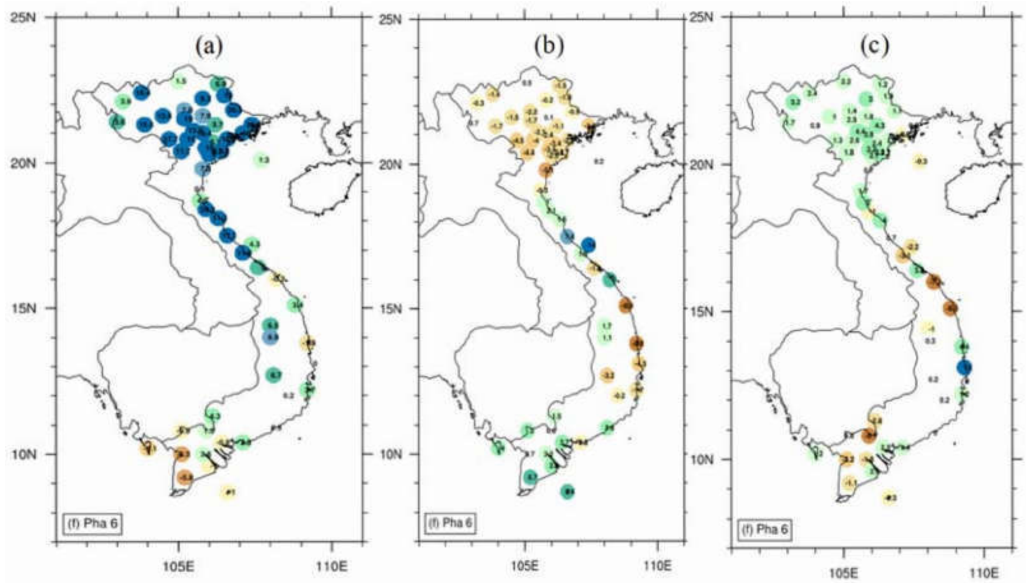

Fig. 15. The rainfall anomaly of phase 5 in Viet Nam in transition months, including: (a) September, (b) October and (c) November.

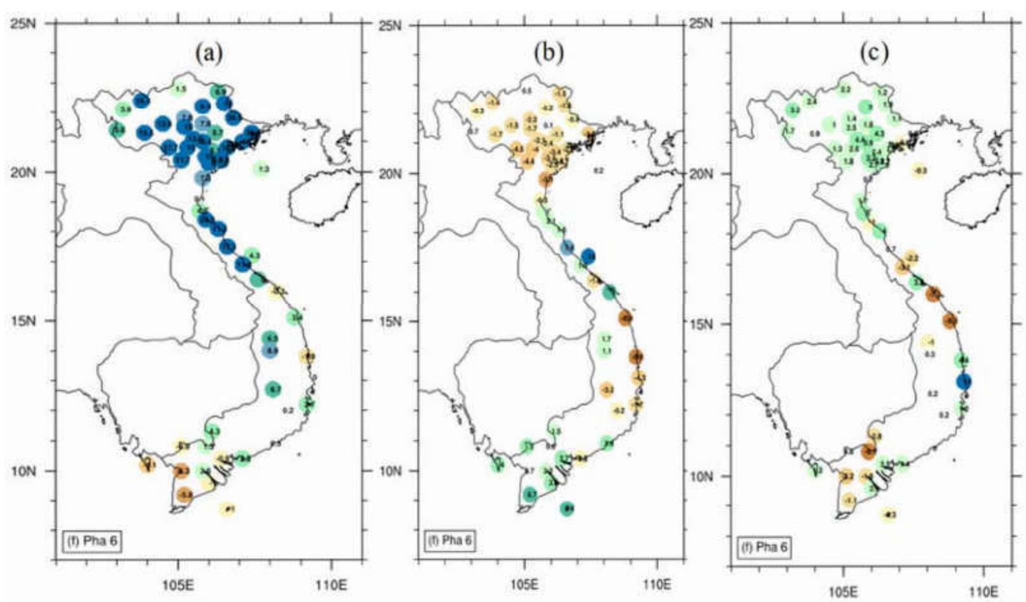

Fig. 16. The rainfall anomaly of phase 6 in Viet Nam in transition months, including: (a) September, (b) October and (c) November.

In phase 6 (Fig. 16), the mean rainfall anomalies tend to decrease in October and November. But in September, the rainfall anomalies show the highest positive values, especially in the Northern and North Central provinces.

Thus, in transition months, the mean rainfall in each phase tends to be higher than corresponding monthly mean rainfall. It is also higher than DJF or JJA months. The higher rainfall anomalies are often concentrated in phases 4, 5 and then phase 6. In other phases, the rainfall anomalies are more mostly negative.

4. Conclusion

In the Northern provinces, the mean rainfall anomalies in phases 1 and 2 of MJO are higher than in other phases. In the North Central regions, the higher rainfall are in phases 3, 4 and 5. From Middle Central to the Southern provinces, phases 4 and 5 are considered as the wettest phases. However, there are not much differences between phases which have the highest and lowest positive rainfall anomalies.

Although MJO is a tropical oscillation, its influence on rainfall distribution in Vietnam is not only in the Southern provinces but also in the Northern provinces. Phase 4 and phase 5 are two phases where the MJO increases rainfall anomalies in Vietnam; the next wet phases are 3, 6 and 7. During transitional seasons, positive rainfall anomalies tend to be higher than summer and winter, especially in September, October and November.

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