Influence of Large-scale circulation features and El Nino conditions on Southwest Monsoon Rainfall 2015 in Sri Lanka

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ABSTRACT

In this study, rainfalldata from 80 rainfall stations and JRA 55 reanalysis data are used to analyse rainfall anomaly distributions over Sri Lanka and large scale circulation anomalies present during SWM 2015. Those circulation anomalies are compared with El Nino composites to see the influence of current El Nino episode on SWM rainfall 2015 over Sri Lanka. Weakening of Mascarene high and Indian low is responsible for diminishing of cross equatorial pressure gradient during SWM 2015. Hence weakening of Somali jet is evident with anomalous north easterly to northerly wind component over Somali area at 850mb level. Weakening of Monsoonal flow with waning of lower tropospheric and mid tropospheric monsoonal wind flow at 700mb and 500mb with anomalous north easterly wind over western Indian ocean and weakening of upper tropospheric tropical easterly jet at 250mb level with anomalous westerly wind component over Sri Lanka is apparent in 2015. Weakening of monsoon flow over Sri Lanka, reduce the orographic rainfall over western slopes of central hills resulting a deficit of seasonal SWM rainfall over that area. With the weakening of monsoonal flow over Sri Lanka coastal convergence may have played an important role of bringing above normal rainfall over southwestern coastal areas. Spatial distribution of rainfall anomaly in SWM 2015 captures the features of spatial distribution of rainfall during El Nino years.

Key words: Monsoon, El Nino, Somali Jet, Tropical easterly jet

1. Introduction:

South West Monsoon (SWM) rainfall 2015 over Sri Lanka has been significantly below normal over interior parts of the Southwest quarter (Fig. 2) where the mid-elevations of the western slops (Ginigathhena- 3267 mm, Watawala- 3252 mm, Norton- 3121 mm) receives highest rainfall in SWM season according to the Department of Meteorology records. By the end of September, 2015 the water levels in major reservoirs had come down to 35 percent and the hydropower generation had been reduced to 20 percent according to the System Control General Manager of Ceylon Electricity Board (CEB).

Extremes in year-to-year variations of long-term mean precipitation of SWM manifest themselves in the form of large-scale floods and droughts (Parthasarathy and Mooley, 1978; Shukla, 1987; Mooley and Shukla, 1987) and cause devastating human and economic loss and adversely affect the agricultural production in the region (Parthasarathy et al., 1988; Webster et al., 1998; Abrol and Gadgil, 1999).

Asian monsoon and El Nino Southern Oscillation (ENSO) are two of the most important components of the tropical coupled ocean atmosphere system. The tropical temporal climate variability is controlled by life cycles of these large scale climate systems, which also interact with each other. For example, the Asian Monsoon is a part of strong annual tropical cycle. On the other hand the main source of tropical interannual variability is ENSO. Both monsoon and ENSO are also mutually and inversely related through large scale convective and circulation patterns in the atmosphere (Lau and Yang, 1996).

Objective of this study is to analyse large scale circulation anomalies associated with SWM 2015 and to identify the possible influence of large scale teleconnections for the deficit of SWM rainfall especially over interior parts of Southwest quarter of the island.

2. Data and Methodology

Daily rainfall data from 80 stations (Fig 1) in Sri Lanka covering the period of June 01 to September 30, 2015 were used. Due to the delay of onset and withdrawal of SWM this period was selected for the analysis.

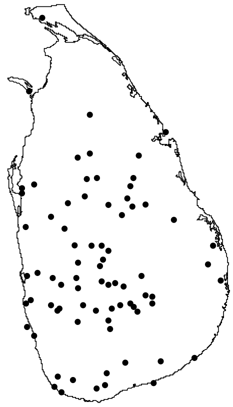

Fig 1. Locations of 80 Rainfall stations in SL used in this study.

Japanese 55-year Reanalysis (JRA-55; Ebita et al. 2011) is used for analysis data. JRA-55 is a third generation reanalysis spans 1958-2012. Japanese 55-year Reanalysis (JRA-55) project conducted by the Japan Meteorological Agency (JMA) for the period from 1958 onward (Kobayashi et al. 2015) with horizontal resolution of 1.25^0 x 1.25^0.

El Nino episode are categorized using Ocean Nino Index (ONI) based on 3 month running mean of SST anomalies in the Niño. The ONI (Oceanic Niño Index) is defined as 3-month running-mean values of SST departures from average in the Niño-3.4 region (5°N-5°S, 120°-170°W). Based on the ONI, NOAA defines El Niño as *positive* ONI greater than or equal to 0.5°C. El Niño episode is classified when these conditions are satisfied for a period of at least five consecutive months (Climate Prediction Center). Anomaly of Seasonal rainfall and rainfall departure from seasonal median was constructed for the period from June 01 to September 30, 2015 to see the seasonal rainfall variability.

Composites of large scale circulation anomalies over the South Asian region associated with El Nino years (Table 1) were constructed to explain the observed changes in large scale circulation pattern during SWM 2015.

El-nino years	1972, 1976, 1982, 1986, 1987, 1991, 1994, 1997, 2002, 2004, 2006

Table 1.

3. Results and Discussion

3.1 SWM 2015 Rainfall distribution

SWM 2015 rainfall over Sri Lanka has been significantly below normal over interior parts of the Southwest quarter such as Kegalle, Ratnapura, Kandy and Nuwaraeliya districts. Within southwest quarter only south western coastal belt receives above normal rainfall.

The economic importance of SWM seasonal rainfall over western slopes of central hills is huge because most of hydro power reservoirs are located in this area. Deficit in seasonal rainfall bring down the water levels in major reservoirs 35 percent and the hydropower generation had been reduced to 20 percent according to CEB. Badulla and Bandarawela located in the eastern slopes of the central hills received above normal rainfall during SWM 2015. It is found that 80% to 100% of the rainy days occurred over Badulla and Bandarawela in SWM 2015 are contributed by thunderstorms.

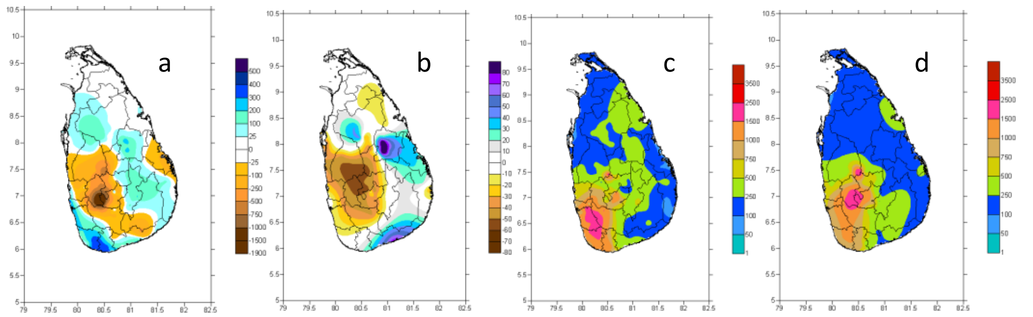

Fig 2. Rainfall anomaly during SWM (June to September) 2015(a), Percentage of departure from seasonal median during SWM 2015(b) Mean seasonal rainfall SWM 2015(c) and Climatology of SWM Rainfall (1961 to 1990) (d).

3.2 Large scale circulation anomalies during SWM 2015

SWM, as an important component of the global monsoon system, is driven by cross-equatorial pressure gradient between the Indian low over the Asian continent and the Mascarene high in the southern Indian Ocean (Thomas and Webster 1997; Fasullo and Webster 2003). This is a uniquely coupled, bi-hemispheric system; nowhere else on Earth does cross-equatorial transfer of heat and momentum compare in magnitude or meridional extent. The Indian low is driven both by direct sensible heating of the Asian continent, particularly the Tibetan Plateau, and by subsequent latent heat release due to moisture supply from the Indian Ocean. The Mascarene high is forced by the subsiding branch of the Southern Hemisphere Hadley cell owing to the Equator-to-Antarctica temperature gradient and can be enhanced during the development of monsoonal circulation (Fasullo and Webster 2003). The Mascarene high is one of the important features of the tropical general circulation which has profound influence on South Asian climate and weather. The position and intensity of this high are considered to be closely linked to the South Asian summer monsoon activity. Although it is a semi-permanent circulation feature, it is more prominent during the northern hemispheric summer (Ananthakrishnan et. al. 1968).

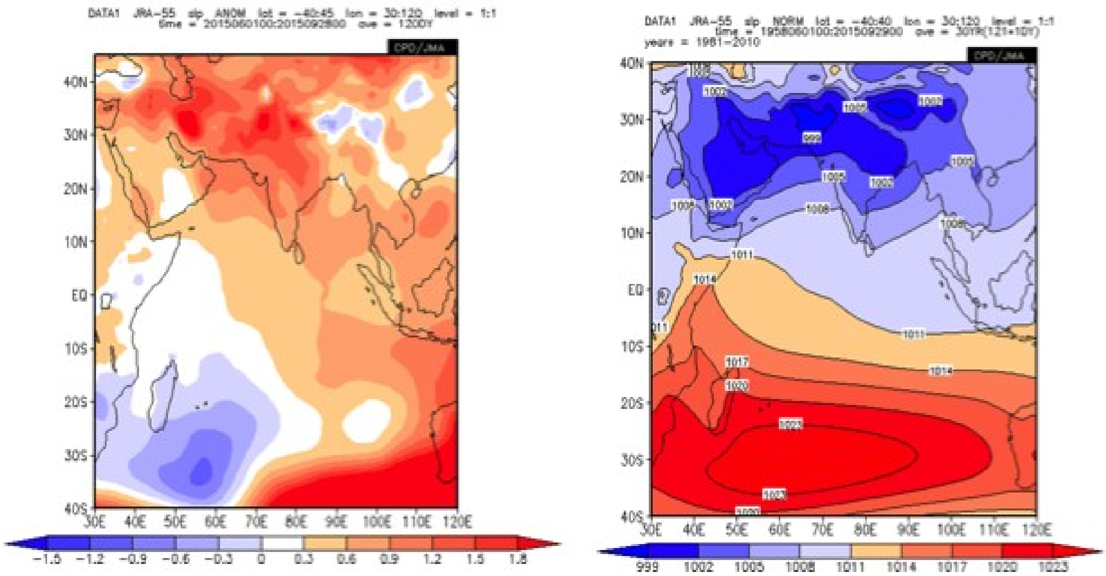

Fig 3. Sea level pressure (SLP) anomalies during SWM 2015 (Left) and Climatology of SLP during SWM (right)

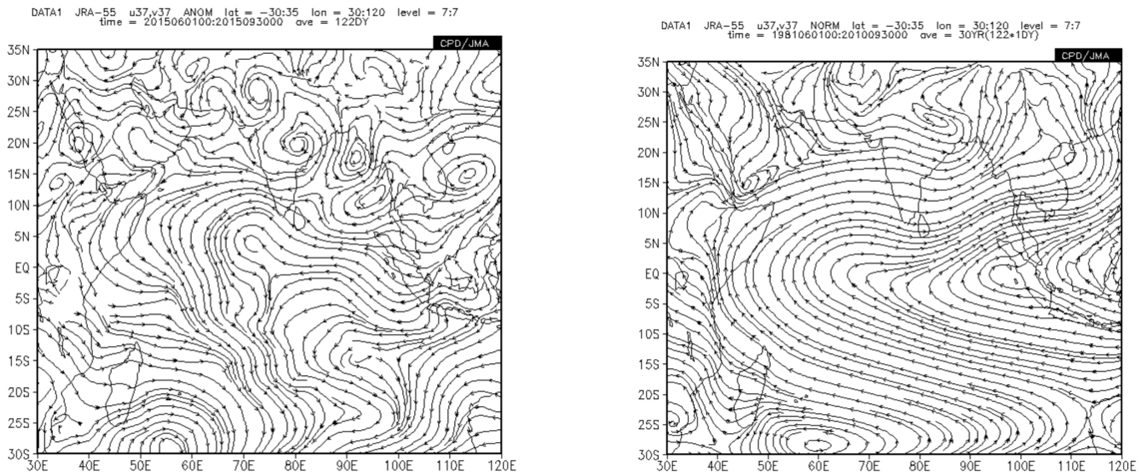

Fig 4. 850mb wind anomalies during SWM 2015 (left) and Climatology of 850mb wind during SWM (right)

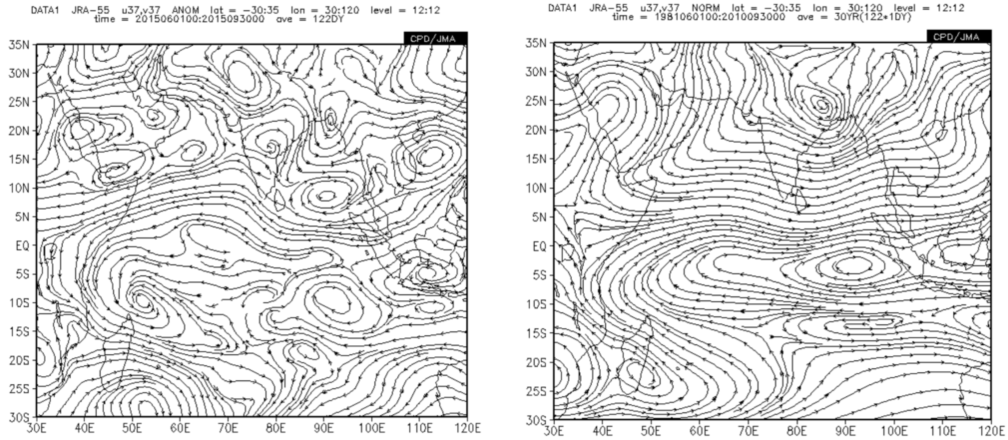

Fig 5. 700mb wind anomalies during SWM 2015 (left) and Climatology of 700mb wind during SWM (right)

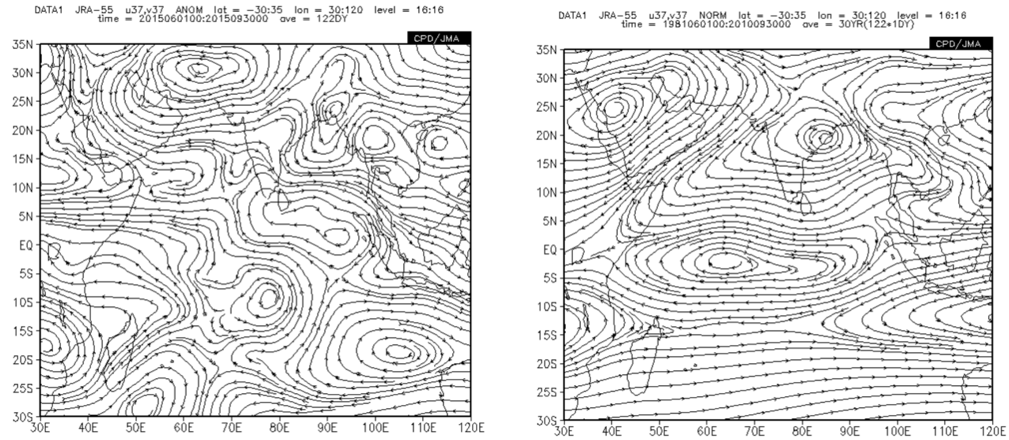

Fig 6. 500mb wind anomalies during SWM 2015 (left) and Climatology of 500mb wind during SWM (right)

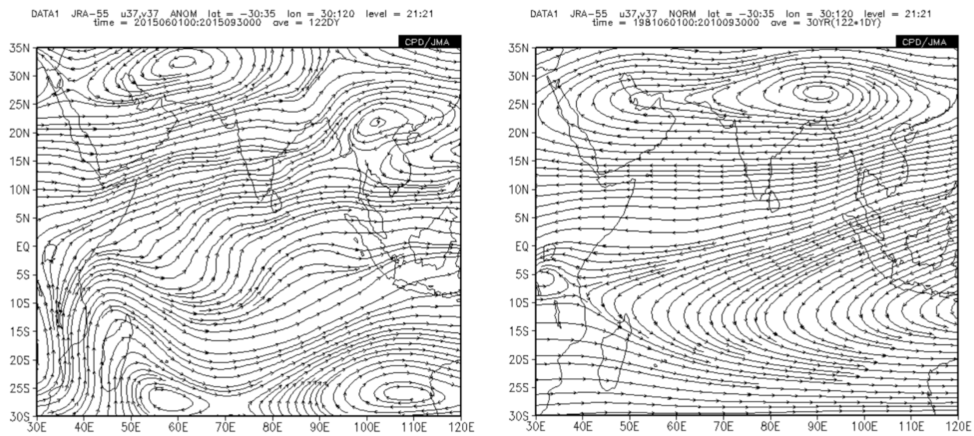

Fig 7. 250mb wind anomalies during SWM 2015 (left) and Climatology of 250mb wind during SWM (right).

The intensification of the Mascarene high strengthens the cross-equatorial flow in the form of the East African Low-Level jet (Somali jet) and the corresponding monsoon current over the Arabian Sea (Sikka and Gray, 1981). Weakening of Mascarene high in the southern Indian Ocean with negative SLP anomalies and Indian low over Asian with positive SLP anomalies is clearly evident during SWM 2015 (Fig 3). Hence weakening of cross equatorial pressure gradient is evident. Weakening of Somali jet is also evident with anomalous north easterly to northerly wind component over Somali area at 850mb level (Fig 4). Waning of lower tropospheric and mid tropospheric monsoonal wind flow is obvious at 700mb and 500mb with anomalous north easterly wind over western Indian ocean (Figs 5 and 6). Weakening Upper tropospheric tropical easterly jet also evident in 250mb level with anomalous westerly wind component over Sri Lanka (Fig 7). With the weakening of Southwest monsoon flow from lower troposphere to upper troposphere over the region, weakening of monsoon flow over Sri Lanka with anomalous south easterly to easterly winds at lower troposphere (850mb and 700mb) (Fig 4 and 5) and with anomalous anti-cyclonic circulation at 500mb to south of Sri Lanka is apparent (Fig 6). Weakening of monsoon flow over Sri Lanka, reduce the orographic rainfall over western slopes of central hills resulting a deficit of seasonal SWM rainfall over this area.

3.3 Possible influence of strong El Nino conditions developed in equatorial Pacific

The ENSO is one of the global scale climate phenomena that have significant influence on the year-to-year variability of the SWM rainfall as well as the surface temperatures over South Asia. In March 2015, weak El Nino conditions were established over the equatorial Pacific which strengthened to moderate level in early June and then to strong level in July 2015. Models and expert opinion also suggest that sea surface temperatures in the east-central tropical Pacific Ocean are likely to exceed 2° Celsius above average, potentially placing this El Niño event among the four strongest events since 1950 (1972-73, 1982-83, 1997-98). El Niño conditions are known to strengthen the northeast monsoon circulation and enhance the rainfall over the region. However, their impact on the regional rainfall distribution varies from year to year.

El Nino composites of SLP anomaly (Fig. 9) shows similar patterns with weakening of Mascarene high with negative SLP anomalies and Indian low with positive SLP anomalies similar to those of SWM 2015 but intensity of anomalies are less compare with SWM 2015 (Fig. 3). El Nino composites of 850mb (Fig. 10 (left)), 700mb (Fig. 10 (right)) and 250mb (Fig. 11 (right)) wind anomaly reveal the same pattern as in SWM 2015. Intensity of anomalies is stronger SWM 2015. The anomalous anti cyclonic circulation appeared over southern Sri Lanka in SWM 2015 is also evident in El Nino composites of 500mb wind anomalies.

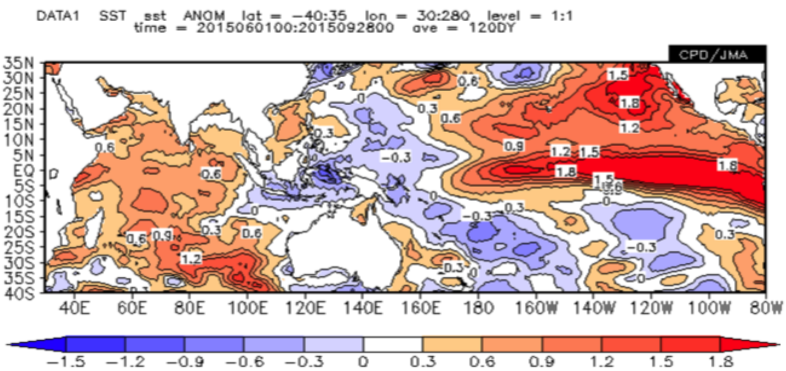

Fig 8. Sea Surface Temperature (SST) anomalies during SWM 2015

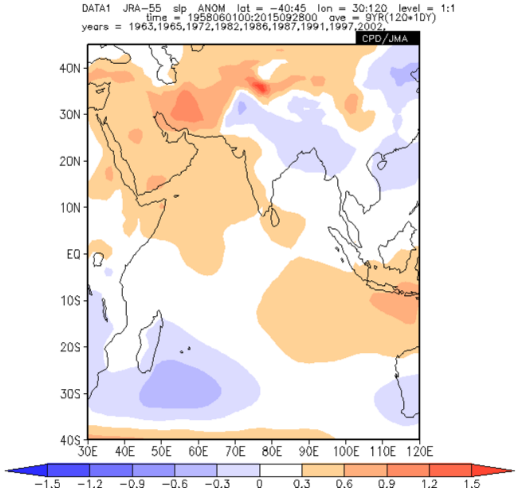

Fig 9. El Nino Composite of SLP anomalies during SWM

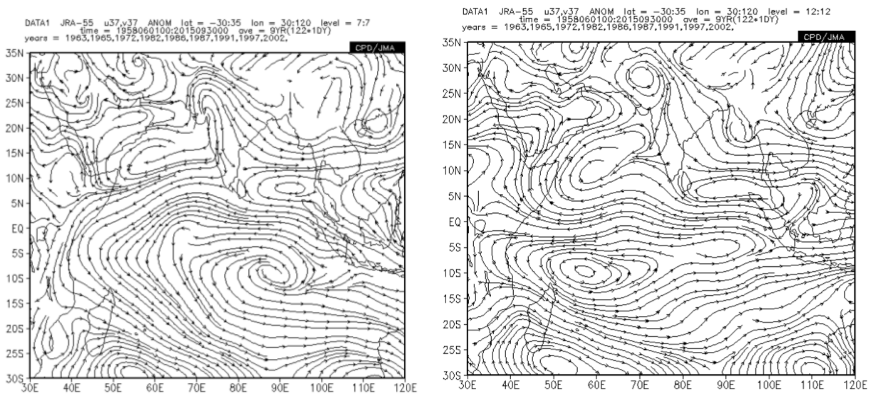

Fig 10. El Nino Composite of 850mb wind anomalies (left) during SWM and El Nino Composite of 700mb wind anomalies(right) during SWM

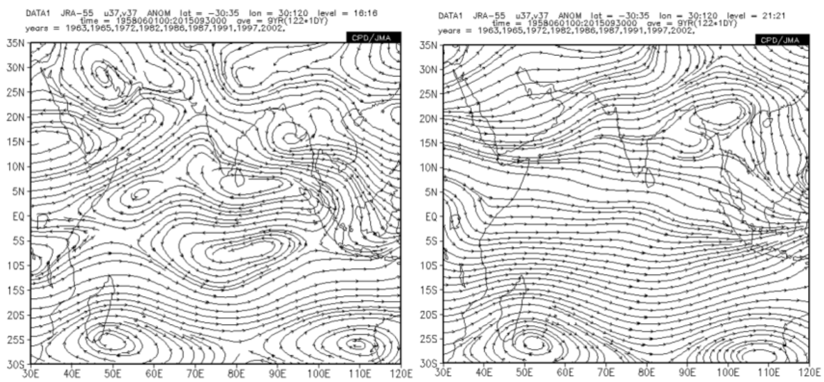

Fig 11. El Nino Composite of 500mb wind anomalies(left) during SWM and El Nino Composite of 250mb wind anomalies(right) during SWM

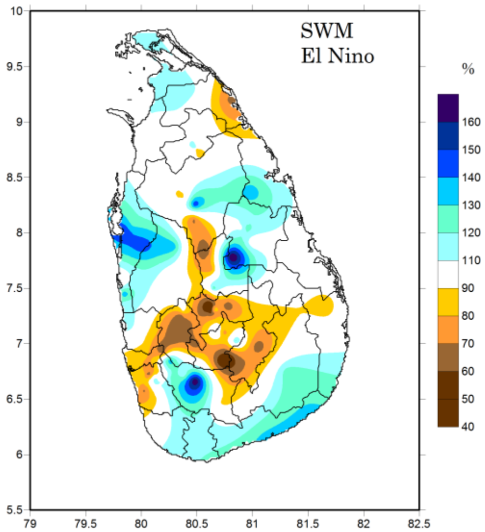

Fig 12. Composites of Seasonal rainfall probabilities (shading) for SWM season during El Nino (Rainfall probabilities refer to the chance of seasonal rainfall exceeding the median, expressed as a ratio with the mean probability (nominally 50%)) (Source: Hapuarachchi and Jayawardena, 2015 (Unpublished)).

4. Summary and Conclusion

South West Monsoon (SWM) 2015 rainfall over Sri Lanka has been significantly below normal over interior parts of the Southwest quarter. Rainfall data from 80 rainfall stations and JRA 55 reanalysis data are used to analyse rainfall anomaly distributions over Sri Lanka and large scale circulation anomalies present during SWM 2015. Those circulation anomalies are compared with El Nino composites to see the influence of current El Nino episode on SWM rainfall over Sri Lanka. Weakening of Mascarene high in the southern Indian Ocean with negative SLP anomalies and Indian low with positive SLP anomalies are clearly evident during SWM 2015. Hence diminishing of cross equatorial pressure gradient is evident. Weakening of Somali jet is also evident with anomalous north easterly to northerly wind component over Somali area is evident in 850mb level. Waning of lower tropospheric and mid tropospheric monsoonal wind flow is obvious at 700mb and 500mb with anomalous north easterly wind over western Indian ocean. Fading of the upper tropospheric tropical easterly jet is also evident in 250mb level with anomalous westerly wind component over Sri Lanka. With the weakening of Southwest monsoon flow from lower troposphere to upper troposphere over the region, weakening of monsoon flow over Sri Lanka with anomalous south easterly to easterly winds at lower troposphere (850mb and 700mb) and with anomalous anti-cyclonic circulation at 500mb to south of Sri Lanka is apparent over the Island. Weakening of monsoon flow over Sri Lanka, reduce the orographic rainfall over western slopes of central hills resulting a deficit of seasonal SWM rainfall over this area. With the weakening of monsoonal flow over Sri Lanka coastal convergence may have played an important role of bringing above normal rainfall over south western coastal areas. The above normal rainfall in the Badulla and Bandarawela located in the eastern slopes of the central hills is mainly due to evening convective thunderstorms. Spatial distribution of rainfall anomaly captures the features of spatial distribution of rainfall during El Nino years (Fig 13). Analysing 60 years rainfall data from 1950 to 2011, Hapuarachchi et al (2015) found that significant influence of El Nino events on SWM rainfall over central parts especially over the western slopes of the central hills of the Island with reduction of seasonal rainfall.

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