Modulation of Seasonal Rainfall in Sri Lanka by ENSO Extremes

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ABSTRACT

Influences of El Niño Southern Oscillation (ENSO) extremes such as El Niño and La Niña events on the seasonal rainfall for four climatic seasons in Sri Lanka are examined by using monthly rainfall data from 90 rainfall stations for the period from 1950-2011.

El Niño and La Niña events such as North-East monsoon (NEM), First Inter monsoon (FIM), South-West Monsoon (SWM) and Second Inter monsoon (SIM) for four seasons were separately considered. El Niño and La Niña events are categorized, according to the Ocean Nino Index (ONI) provided by NOAA Climate Prediction Center.

Out of four climatic seasons, strongest impact can be seen during the SIM season with probability of receiving above - median rainfall over most parts of the Island is high (low) on El Niño (La Niña) events. Western slope of the central hills has a considerable influence during ENSO extremes with suppressed seasonal rainfall during El Niño events and enhanced seasonal rainfall during La Niña events in SWM season. Enhanced and suppressed rainfall activity is evident in Northwestern parts of the island during La Niña and El Niño events respectively during NEM season. Weakest impact of ENSO extremes can be seen during the FIM season.

The analysis provides a useful reference of when and where the ENSO extremes have significant impacts on seasonal rainfall during four climatic seasons that can be used to enhance the skills of seasonal forecasting in Sri Lanka.

Key words: *El Niño Southern Oscillation (ENSO), El Niño (La Niña), Monsoon, Inter-monsoon, Seasonal forecasting*

1. Introduction

Interannual variations in seasonal rainfall can have a profound socio-economic impact. Deficit of seasonal rainfall is associated with droughts and crop failure whereas excess of seasonal rainfall is associated with devastating flood, damage to properties and crops. Seasonal prediction provides important information to a great variety of practical applications, such as water resource management, food security, disaster prevention, agriculture management, and energy supply. Seasonal predictions significantly depend on slowly varying components of the climate system, most significantly sea surface temperatures (SST) across tropical ocean basins. SST can impart a 'memory' to the atmosphere and that 'memory' can be transmitted to parts of the globe remote from the originating sea surface temperature anomalies. This phenomenon is referred as "Teleconnections" by Meteorologists (Troccoli, 2008). The most important component of ocean atmospherics system is the ENSO (El Nino Southern Oscillation) cycle, which refers to the coherent, large-scale fluctuation of ocean temperatures, rainfall, atmospheric circulation, vertical motion and air pressure across the tropical Pacific.

El Niño is characterized by unusually warm ocean temperatures in the Equatorial Pacific, as opposed to La Niña, whichis characterized by unusually cold ocean temperatures in the Equatorial Pacific. Both events develop in association with swings in atmospheric pressure between the tropical indo-pacific and eastern pacific (Mcpheden, Michel, J., 2004).The zonal circulation associated with this pressure pattern is known as the 'Walker Circulation' (Bjerknes, 1969). Sea-level pressure patterns over these regions are influenced primarily by the oceanic phenomena called El Niño and La Niña, which are associated with extremes of sea-surface temperatures (SSTs) over the Pacific Ocean. During El Niño events, SSTs are warmer and the trade winds are weaker than normal in the central and eastern Pacific Ocean and SSTs are cooler than normal in the eastern Indian and western Pacific Oceans. These conditions are reversed during La Niña events (Philander, 1990). El Niño and the Sothern Oscillation together comprise a complex atmosphere–ocean interaction system known as the ENSO phenomenon.

The ENSO phenomenon is responsible for strong inter annual variability of rainfall in the tropics. El Niño and La Niña events also cause droughts and floods over different parts of the globe (Rasmusson and Carpenter, 1983; Ropelewski and Halpert, 1987, 1989; Nicholls and Wong, 1990; Diaz and Kiladis, 1992) and have strong impacts on the economies of the countries they affect.

In previous studies (Rasmusson and Carpenter, 1983; Suppiah, 1989; Sumathipala and Punyadeva 1998; Punyawardena and Cherry, 1999,) correlations between the SO phenomenon and the seasonal rainfall of Sri Lanka were reported. In a companion paper (Suppiah 1996), variations in temporal and spatial correlations between seasonal rainfall of Sri Lanka and the SO phenomenon are discussed?. Strong correlations between the Southern Oscillation Index (SOI) and seasonal rainfall are noticed in the dry zone of Sri Lanka. The dry zone, which occupies two-thirds of Sri Lanka, experiences a prolonged dry period during the south-west monsoon season and has a wet season during the months between October and February. As previous studies, such as (Rasmusson and Carpenter 1983; Suppiah 1989; Suppiah 1996), have used data only up to 1990, impact of ENSO extremes on seasonal rainfall variability during last 2 decades (1990-2010) have not been thoroughly documented.

Premalal, 2013 pointed out that there is a trend for below normal rainfall for the southwest monsoon season (May-September) during El Nino situation, while the trend is above normal during Second Intermonsoon (October-November). The aim of this paper is to investigate the nature of the seasonal rainfall variability with ENSO extreme events. Knowledge of the seasonal rainfall connection to ENSO extremes may lead to enhanced seasonal forecasting skill, because the predictability of an ENSO event is approximately 3-4 months in advance.

The remainder of the paper is organized as follows. Descriptions of the data and analysis method used are presented in section 2. In section 3, the variation of seasonal rainfall with respect to the ENSO extremes are investigated. Finally, a summary and conclusions are presented in section 4

2. Data and Methodology

Monthly rainfall data for the period 1950-2011 from 90 stations in Sri Lanka, were used for this study (Fig 1). Seasonal median was calculated using data from 1961 to 1990. Seasonal median was considered in this study in order to minimize the impact from extreme seasonal rainfall that may significantly contribute to the seasonal mean as well as seasonal anomalies.

El Nino and La Nina episodes are categorized using Ocean Nino Index (ONI) based on 3 month running mean of SST anomalies in the Niño-3.4 region (5ºN-5ºS, 120º-170ºW) (Fig 2). Based on the ONI, *National Oceanic and Atmospheric Administration (NOAA)* defines El Niño as positive ONI greater than or equal to 0.5°C and La Niña as a negative ONI less than or equal to -0.5°C. An El Niño episode is classified when these conditions are satisfied for a period of at least five consecutive months (Climate Prediction Center).

The ENSO being a major source of global predictability on the seasonal time scale, probability composites provide useful information for seasonal prediction. ''Probability composites'' for seasonal rainfall are generated with seasonal rainfall data for the period from 1950 to 2011 by counting the number of seasons at each station for which seasonal rainfall was greater than a predefined threshold, and then dividing by the total number of seasons during El Nino and La Nina separately to form a composite probability. Here we used the median of seasonal rainfall as predefined threshold at each station. The seasonal median is a function of station and season. Spatial Distribution of Median rainfall for each season is given for left side in Figures 3 to 6. In this study, probability of above median rainfall was considered in to avoid the influence from extreme seasonal rainfall. Further probability composite maps can be readily used in seasonal predictions.

The seasonal median is a function of station and season. Spatial Distribution of Median rainfall for each season is given for left side in each of the Figures from 3 to 6. In this study, probability of above median rainfall is considered to minimize the impact from extreme seasonal rainfall that may significantly contribute to the seasonal mean as well as seasonal anomalies. Further probability composite maps can be readily used in seasonal predictions.

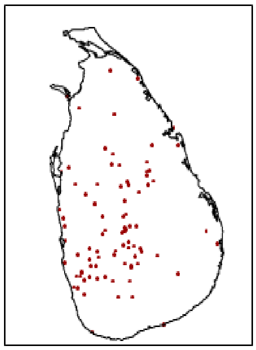

Fig. 1: Locations of 90 Rainfall Stations in Sri Lanka

El Niño and La Niña events during the considered periods are listed in Table 1 below.

	NEM	FIM	SWM	SIM
Number of El-Niño Event	23	11	16	21
Number of La-Niña Event	18	15	14	18

Table 1: The number of El Nino and La Nina events, based on ONI Index during the 61 SWM, NEM, FIM and SIM seasons recorded from 1950 to 2011

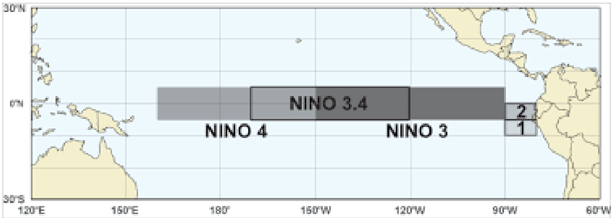

Figure 2 : Ocean Nino Index (ONI) based on 3 month running mean of SST anomalies in the Niño 3.4 region (5ºN-5ºS, 120º-170ºW) (http://www.bom.gov.au/climate/enso/indices/about.shtml)

3. Results and Discussion

3.1 Impacts of ENSO Extremes during SWM season.

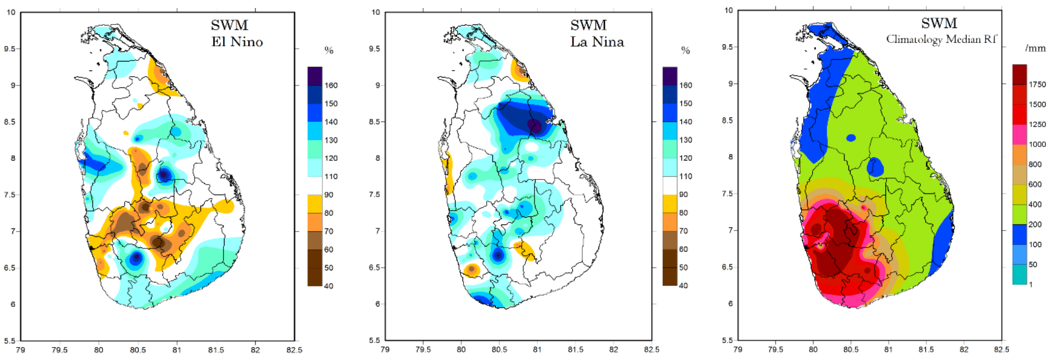

Fig: 3: Composites of Seasonal rainfall probabilities (shaded) for SWM season during El Nino (left) and La Nina (Middle). Climatological SWM median rainfall (mm) (right).Rainfall probabilities refer to the chance of seasonal rainfall exceeding the median, expressed as a percentage with the mean probability (nominally 50%).

In southwest monsoon, winds originate in the southwest, bringing moisture from the Indian Ocean. When these winds encounter the slopes of the Central Highlands, they unload heavy rains on the mountain slopes and the southwestern sector of the island. Southwest monsoon rains are experienced at any time of the day and night; sometimes intermittently, mainly in the South-western part of the country. The highest rainfall was received by the mid-elevations of the western slopes, up to 2,500 mm (98.4 in) of rain per month, but the leeward slopes in the east and northeast received little rain.

Composite of probability of receiving above median seasonal rainfall during El Nino years (Fig 3 left) indicates reduction of seasonal rainfall over central parts of the Island. Conversely, southern parts of the island indicate higher probability of receiving excess of seasonal rainfall. During La Nina years central parts of the Island receives excess of seasonal rainfall in contrast to El Nino years. Sri Lanka's power generation is still dependent on hydropower facilities to a great extent and most of the hydropower reservoirs are located along the western slopes of the central hills that receive substantial amount of rainfall during SWM. This strong influence of ENSO extremes on inter-annual rainfall variability in SWM over western slopes of the central hills would have a significant impact on hydropower generation in Sri Lanka.

3.2 Impacts of ENSO Extremes during NEM season.

Dry and cold wind blowing from the Indian land-mass will establish a comparatively cool, but dry weather over many parts making the surrounding pleasant and comfortable weather except for some rather cold morning hours. Cloud-free skies provide days full of sunshine and pleasant and cool night. During this period, the highest rainfall figures are recorded in the North, Eastern slopes of the hill country and the Eastern slopes of the Knuckles/Rangala range. NEM particularly affects the dry zone of the Island, since the livelihood of the people in the dry zone is highly dependent on agriculture. The main water source of dry zone is NEM Rainfall for cultivating the paddy. As majority of irrigation tanks are located in the dry zone, seasonal NEM rainfall is of immense importance for Agriculture, as well as for? Water management. The production of rice, which is one of the principle crops in Sri Lanka, is highly susceptible to rainfall variability, both deficient and excess rainfall conditions were found to have significantly contributed to reduction of rice yields (Yoshino and Suppiah, 1984).
During El Nino years (Fig: 4 left) reduction of seasonal rainfall is obvious over North western, North central and central parts of the Island in NEM. In contrast, most parts of the island indicate higher probability of receiving excess of seasonal rainfall during La Nina years, except for Western province and Northeastern coastal areas of the Island. Impact during La Nina years is much stronger than El Nino years. Contrasting rainfall pattern with suppressed seasonal rainfall in El Nino years and enhanced seasonal rainfall in La Nino years is clearly evident over Northwestern parts. The economic impact of inter-annual rainfall variations in NEM is huge because major irrigation reservoirs located in Northwestern and North central parts of the island receive a significant amount of annual rainfall from the NEM.

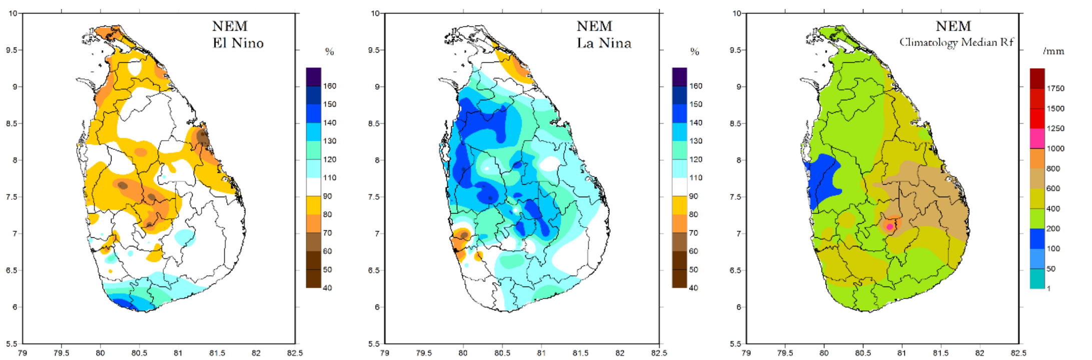

Fig: 4 composites of Seasonal rainfall probabilities (shaded) for NEM season during El Nino (left) and La Nina (Middle). Climatological NEM median rainfall (mm) (right). Rainfall probabilities refer to the chance of seasonal rainfall exceeding the median, expressed as a percentage with the mean probability (nominally 50%).

3.3 Impacts of ENSO Extremes during FIM season.

In Sri Lanka, the intermonsoonal period occurs from March until mid-May, with light, variable winds and evening thundershowers over the Island. Warm and uncomfortable conditions, with thunderstorm-type rain,Particularly during the afternoon or evening, are the typical weather conditions during this season. Distribution of rainfall during this period shows that the entire South-western sector of the hill country receiving 250 mm of rainfall, with localized areas? On the South-western slopes experiencing rainfall in excess of 700 (mm).

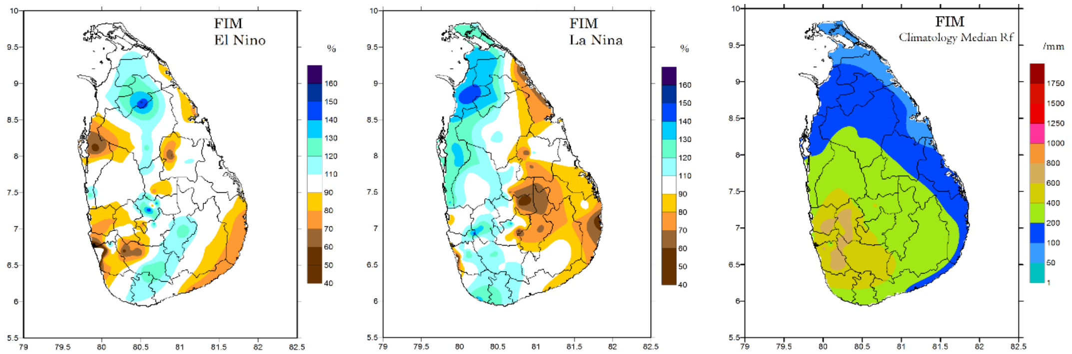

Fig: 5 composites of Seasonal rainfall probabilities (shading) for FIM season during El Nino (left) and La Nina (Middle). Rainfall probabilities refer to the chance of seasonal rainfall exceeding the median, expressed as a ratio with the mean probability (nominally 50%). Climatological FIM seasonal median rainfall (mm) (right).

Weakest influence of ENSO extremes on seasonal rainfall is evident during FIM. During the FIM seasons, and both positive and negative rainfall departures were observed for El Niño and La Niña events (Fig 5). During FIM formation of mesoscale circulation due to land surface heating is the premium mechanism for rainfall activities in Sri Lanka. Convective showers during the FIM period are often isolated and localized predominately over land, generally initiated by sea breezes and other local circulations and orography. This may be the reason for weak influence of large scale phenomena like ENSO on seasonal rainfall in FIM.

3.4 Impacts of ENSO Extremes during SIM season.

During this season, thunderstorm-type rain, particularly during the afternoon or evening, is common. Unlike in the FIM season, the influence of weather systems such as depressions and cyclones in the Bay of Bengal is common during the SIM season. Under such conditions, the whole country experiences strong winds with widespread rain, sometimes leading to floods and landslides. The SIM period of October – November is the period with the most evenly balanced distribution of rainfall over Sri Lanka. Almost the entire island receives in excess of 400 mm of rain during this season, with the South-western slops receiving higher rainfalls in the range 750mm to 1200 mm.

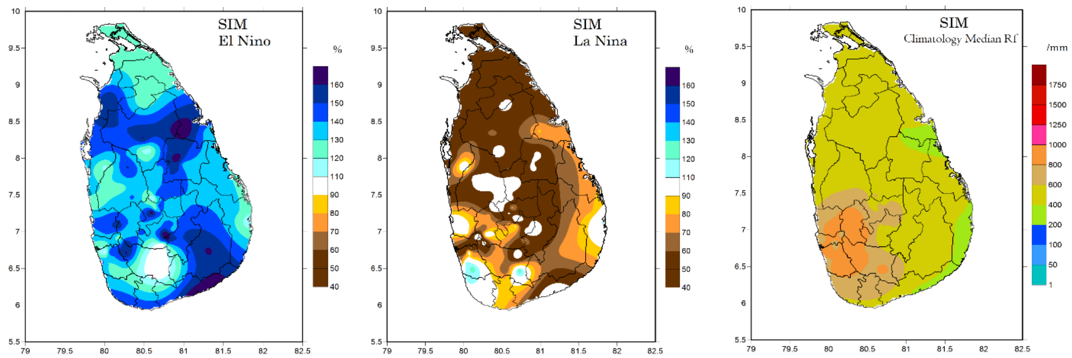

Fig. 6. Composites of Seasonal rainfall probabilities (shading) for SIM season during El Nino (left) and La Nina (Middle). Rainfall probabilities refer to the chance of seasonal rainfall exceeding the median, expressed as a ratio with the mean probability (nominally 50%). Climatological SIM seasonal median rainfall (mm) (right).

Results of the present study indicate strong influences of extreme phases of the ENSO phenomenon on the seasonal rainfall of Sri Lanka. Strongest influence of ENSO extremes is evident during SIM. Spatial patterns of seasonal rainfall in probability composite maps show clear contrasts between El Niño and La Niña events during the SIM seasons. These contrasting spatial patterns are evident in most parts of Sri Lanka, which experience an excess of seasonal rainfall during El Nino years and deficit of seasonal rainfall in La Nina years (Fig 6). Large rainfall anomalies during El Niño and La Niña events during the SIM season have been widely reported in previous studies (Rasmusson and Carpenter, 1983; Behrend, 1987; Suppiah, 1988, 1989)

4. Summary and Conclusion

Influences of extremes of the ENSO phenomenon on the rainfall of Sri Lanka have been studied using probability composites of receiving above median seasonal rainfall for four climatic seasons, namely SWM, NEM, FIM and SIM using rainfall data from 90 stations and ONI index from 1950-2011.

Results of the present study indicate strong influences of extreme phases of the ENSO phenomenon on the seasonal rainfall of Sri Lanka. The Strongest influence of ENSO extremes is evident during SIM with contrasting spatial patterns are evident in most parts of Sri Lanka, which experience an excess of seasonal rainfall during El Nino years and a deficit of seasonal rainfall in La Nina years.

Significant impact of SWM rainfall was also evident over central parts of the Island with reduction of seasonal rainfall during El Nino events and enhanced seasonal rainfall during La Nina events. The impact of ENSO extremes on SIM and SWM is consistent with findings of previous studies.

Significant impact of NEM rainfall is also profound over North western, North central and central parts of the Island with reduction of seasonal rainfall during El Nino events and enhanced seasonal rainfall during La Nina events. Most of the previous studies found that rainfall anomalies during the NEM seasons do not show a clear contrast in their temporal patterns.

Weakest influence of ENSO extremes on seasonal rainfall is evident during FIM with no clear contrast in the temporal pattern.

This study implies that the inter-annual variability of seasonal rainfall is largely influenced by the ENSO extremes over Sri Lanka during SIM, SWM and NEM seasons. The analysis provides a useful reference of when and where the ENSO extremes have significant impacts on seasonal rainfall during four climatic seasons in Sri Lanka. This information can be used to enhance the skills of seasonal forecasting in Sri Lanka.

A detailed analysis on large scale circulation features during ENSO extremes is suggested to examine how the rainfall variations are associated with large-scale low-level circulations.

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