

## Impact of the Intra-seasonal Oscillations (ISO) on rainfall variability during Southwest Monsoon (SWM) in Sri Lanka

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### Abstract

The intra-seasonal oscillation (ISO) refers to variability on timescales of 20-100 days. This range of timescale is in between the typical timescales for weather (up to 15 days) and climate (from a season and beyond). Even though substantial progress has been made in recent years on the development and applications of medium-range weather forecasts and seasonal climate predictions, forecasting on the intra-seasonal time scale has received much less attention, in part because this time horizon has been considered a 'predictability desert'.

Intra-seasonal prediction is a crucial planning window for the agricultural and energy sectors, water resource managers and other stakeholders. ISOs are near global patterns of anomalous atmospheric circulation that are closely related to variations in precipitation in many regions of the tropics.

The impact of the two dominant modes of ISO, Madden Julian Oscillations (MJO), and Boreal Summer Intra-Seasonal Oscillations (BSISO) on southwest monsoon (SWM) seasonal rainfall in Sri Lanka is investigated using the Real-time Multivariate MJO (RMM) index (Wheeler and Hendon 2004) and BSISO indices (Lee et al. 2013) respectively and the observational rainfall data from 1981 to 2010. Composite maps of circulation anomalies and rainfall anomalies, each for eight MJO, BSISO 1 and BSISO2 phases are constructed.

This study provides a useful reference of when and where the MJO and BSISO have significant impacts on rainfall variability during SWM season in Sri Lanka. This information can be used along with the accurately predicted the MJO and BSISO phase by dynamical or statistical models, to improve intra-seasonal prediction in Sri Lanka. Several empirical and statistical models have been developed to predict the MJO and BSISO and useful predictive skill of the MJO and BSISO from these empirical models can reach a lead time of about 15–20 days at present.

### Introduction

The intra-seasonal oscillations (ISOs) are near global patterns of anomalous atmospheric circulation that are closely related to variations in precipitation in many regions of the tropics. Pioneer studies discovered that there are two dominant components in the intra-seasonal timescale; one is an eastward propagating component, which is commonly referred to as Madden Julian Oscillations (MJO)<sup>1,2</sup> (Madden and Julian, 1971; 1972), the other is a northward propagating component associated with the Asian summer monsoon referred to as Boreal Summer Intra-Seasonal Oscillations (BSISO)<sup>3-6</sup>.

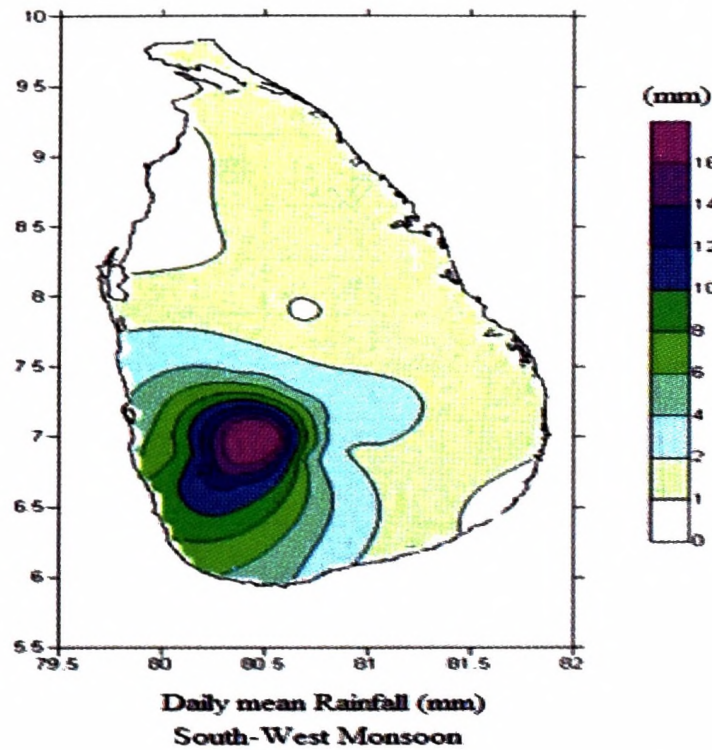
The importance of the ISO to tropical and global weather and climate has become increasingly apparent. The direct impacts of the ISO on tropical weather and climate phenomena have been widely documented. For instance, the ISO can influence the onset of and breaks in the summer monsoons over Asia, Australia, America, and Africa.

Intra-seasonal prediction is a crucial planning

window for agricultural sector, water resource managers, energy sector and other stakeholders. Numerous agricultural decisions can be made given forecasts targeted to the intra-seasonal time scale. Reliable predictions for this period in advance would help making decisions on for key, high impact, events such as the timing of rainy season onset for planting, cessation for harvesting, provide early warning for risk of potential dry spells or damaging heavy rain for crop management and protection decisions in agriculture<sup>13</sup>.

During the Southwest Monsoon (SWM) season, May to September, western slopes of central highlands receive significant amount of rainfall (Fig 1) and southwestern coastal belt around 5-10 mm daily rainfall (Fig 1). In general, the dry zone (northern, eastern, northwestern and northeastern Sri Lanka) receives less rainfall during SWM season. Long lasting monsoon rains may result in floods in low-lying areas and landslides in hilly areas. Rains can be experienced at any time during day and night. The SWM rainfall in Sri Lanka involves multiscale variations. Among them,

the intraseasonal variation is prominent, which often causes severe flood or drought and greatly impacts people, as well as the development of economy and agriculture. Sri Lanka's power generation is still dependent on hydropower facilities to a significant extent and changing patterns of rainfall would have an impact on it.



**Fig. 1.:** 30 year average (1981-2010) daily rainfall for Southwest Monsoon season.

The main objective of this paper is to investigate the impact of the MJO as well as BSISO on rainfall variability for SWM.

The remainder of the paper is organized as follows. Descriptions of the data and analysis method used are presented followed by an investigation into, the variation of rainfall with respect to the MJO and BSISO during SWM.. Finally, a summary and conclusions are presented in section 4.

## Data and Methodology

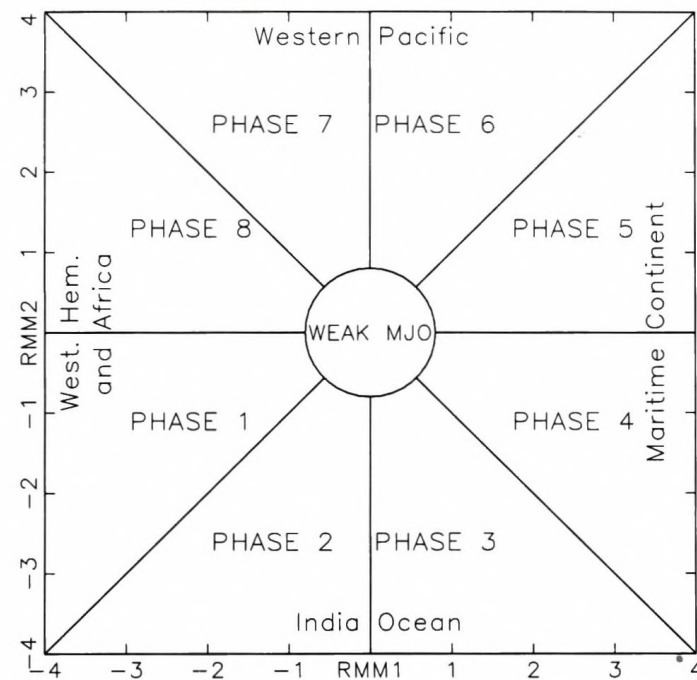
### Rainfall Data

The daily rainfall data recorded by the Department of Meteorology, Sri Lanka for 24 stations from Jan. 1981 to Dec. 2010 is used in the study.

### MJO index

The MJO index, a real-time multivariate MJO (RMM) index<sup>14</sup>, downloaded from the website of the Bureau of Meteorology, Australia (<http://www.bom.gov.au/bmrc/clfor/cfstaff/matw/maproom/RMM/>) was used in the study. This index defines the MJO through projection of daily anomaly data onto the leading pair of empirical orthogonal functions (EOFs) of combined fields of equatorially-averaged (15°S–15°N) Outgoing Longwave Radiation (OLR), 850 hPa zonal wind, and 200 hPa zonal wind, to obtain two principal component time

series (called RMM1 and RMM2). The RMM1 and RMM2 index defines a 2D phase space. This phase space is used to define eight “strong” MJO phases, each corresponding to the geographical position of its active convective center (labeled 1–8 in Fig. 2), and a “weak MJO” category defined when the amplitude is less than 1. These phases make up a full MJO cycle originating from the western Indian Ocean and decaying over the central Pacific.



**Fig. 2.** Phase space represented by the 2-component MJO index (RMM1, RMM2)<sup>14</sup>. Eight defined regions of the phase space are labeled, as is the region considered to signify weak MJO activity. Also labeled are approximate locations of the enhanced convective signal of the MJO for that location of the phase space, e.g. “Indian Ocean” for phases 2 and 3.

### BSISO Indices

The amplitude and phase of BSISO is defined using two real-time indices: BSISO1 and BSISO2, based on multivariate empirical orthogonal function (MV-EOF) analysis of daily anomalies of outgoing longwave radiation (OLR) and zonal wind at 850 hPa (U850) in the region 10°S–40°N, 40°–160°E, for the extended boreal summer (May–Sep.) season over the 30-year period, 1981–2010<sup>15</sup>. BSISO1 is defined by the first two principal components (PCs) of the MV-EOF analysis, which together represent the canonical northward propagating variability that often occurs in conjunction with the eastward MJO with quasi-oscillating periods of 30–60 days. BSISO2 is defined by the third and fourth PCs, which together mainly capture the northward/northwestward propagating variability with periods of 10–30 days during primarily the pre-monsoon and monsoon-onset season<sup>15</sup>.

BSISO1 and BSISO2 indices are available online at (<http://www.apcc21.org/eng/service/bsiso/moni/japcc030602.jsp>).

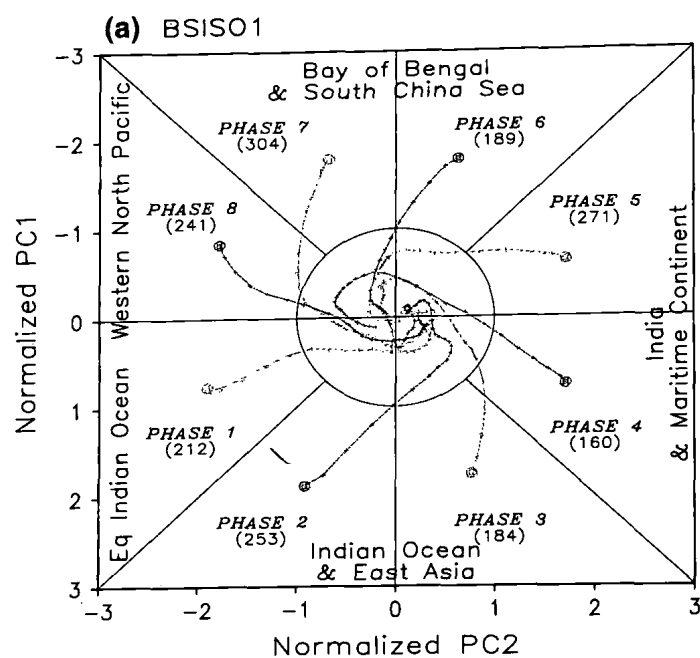


Fig. 3A. PC2 and PC1 phase space composite curves of BSISO1

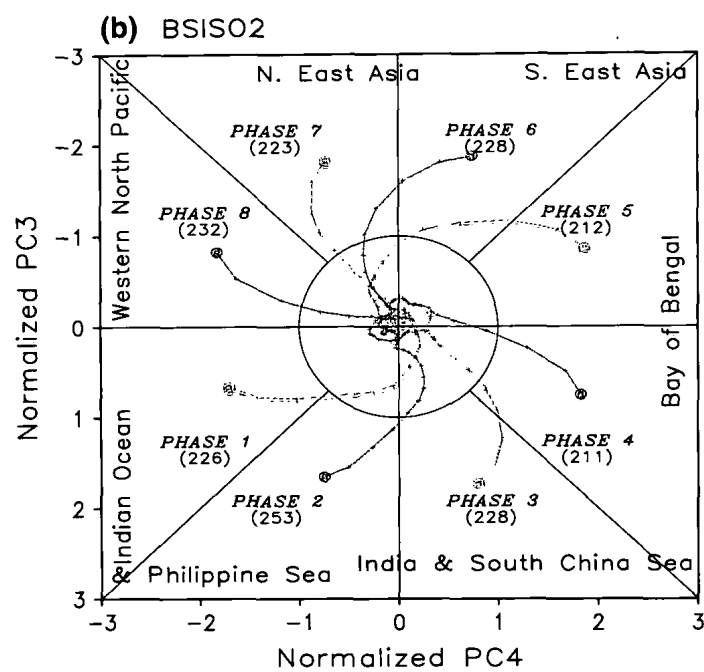


Fig. 3B. PC3 and PC4 phase space composite curves of BSISO2

In Fig. 3a and 3B, the PCs have each been normalized by their respective standard deviation. For each initial phases, strong cases are selected when the BSISO amplitude  $(PC1^2 + PC2^2)^{1/2}$  exceeded  $1.5^{15}$ . Eight defined regions of the phase space are labeled, as is the region considered to signify weak BSISO activity in the middle

#### Composite Analysis

Composites of rainfall and circulation are computed for each of the eight strong phases of the MJO for Southwest Monsoon using 30 years data (from 1981-2010). Composites are formed by assigning every day of the historical record into one of the eight categories. Intensity of MJO of more than 1 represents the strong MJO category. Strong BSISO category is represented by the amplitude of the BSISO being greater than 1.5. Mean value at each phase of MJO and BSISO at a particular station is subtracted from climatological mean (1981-2010) of that station to form anomaly of

each phase. Daily composites are prepared by averaging rainfall anomaly data over the contemporaneous (i.e., with zero lag) days that fall in each MJO and BSISO category for that particular season.

During the 30 SWM seasons, of the analysis period (1981 to 2010) of this study, the maximum number of days under each of the 8 strong BSISO1 and BSISO2 phases are given in Table 1.

Phase	MJO	BSISO1	BSISO2
1	376	150	144
2	315	182	173
3	177	131	165
4	203	125	163
5	284	159,	162
6	295	109	177
7	235	243	137
8	243	174	129

Table 1. Maximum number of days under each of the 8 strong MJO, BSISO1 and BSISO2 Phases during the 30 SWM seasons

#### Results and Discussion

##### Variation of Rainfall during SWM season for different phases of MJO

During phase 1, isolated patches of above normal rainfall anomalies are evident in western parts 1 (Fig 4). During phase 2 widespread positive rainfall anomalies can be seen over the country, with enhanced rainfall anomalies over the western slopes of central hills. Most importantly majority of stations located in North eastern, Eastern and Northwestern parts which are considered as dry zone, receive significant positive rainfall anomalies.

During Phase 3, above normal rainfall anomalies are apparent over southern western part. In Phase 4, the rainfall anomaly pattern was almost similar to that during Phase 3 with slight weakening of the rainfall intensity. The Phases 7 and 8 are associated with the dry signal over Sri Lanka. During phase 8 the strengthening of negative anomalies over Western slopes of Central hills are apparent (Fig. 4).

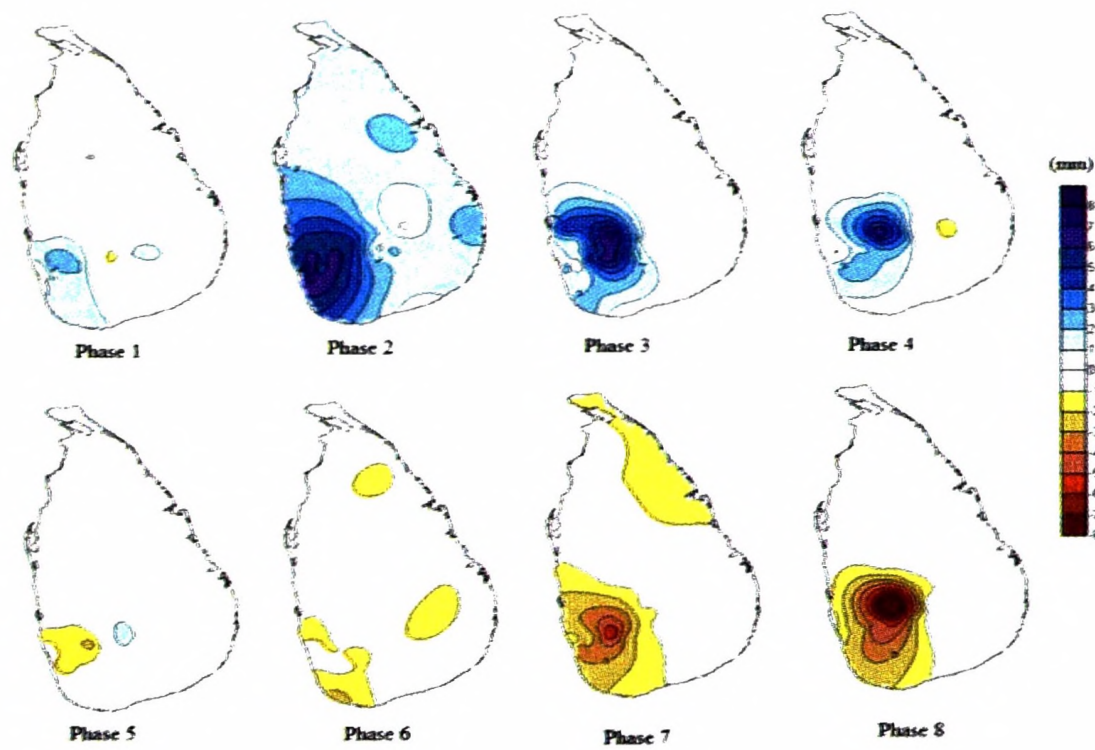


Fig 4 Composites of daily rainfall anomalies (mm) (shading) for SWM season for MJO phases 1–8.

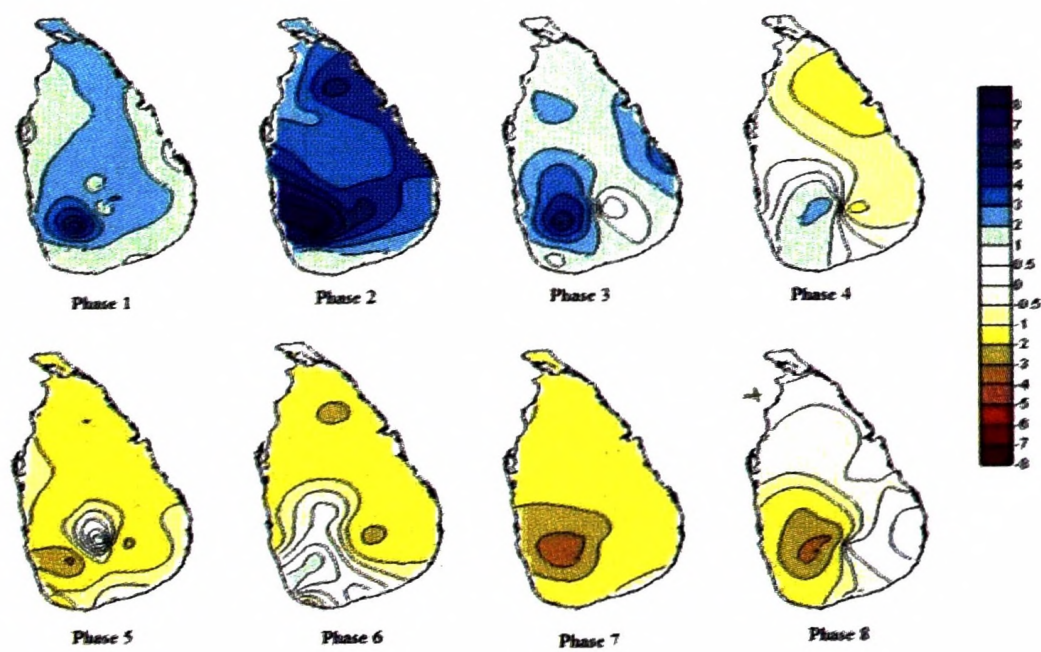


Fig 4. :Composites of daily rainfall anomalies (mm) (shading) for SWM season for BSISO 1 phases 1–8.

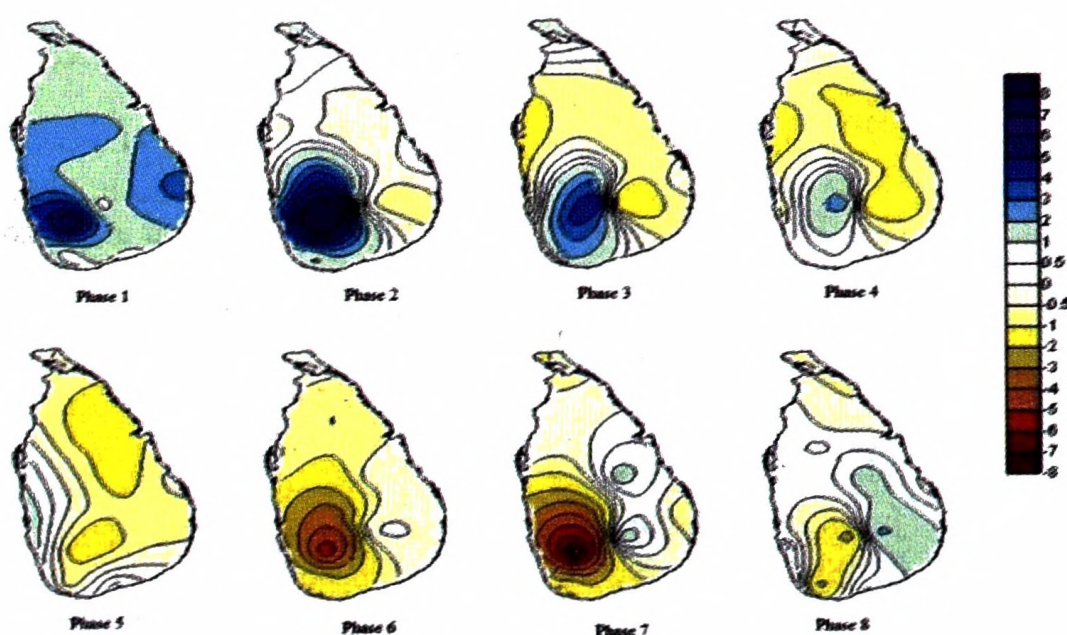


Fig 6. :Composites of daily rainfall anomalies (mm) (shading) for SWM season for BSISO 2 phases 1–8.

*Variation of Rainfall and Circulation Anomalies during SWM season for different BSISO 1/2 phases*

For BSISO 1, widespread positive anomalies are evident in phase 1 to 3 with strengthening of positive anomalies in phase 2 while widespread dry conditions can be seen from phase 5 to 8 with strengthening of negative anomalies apparent over central hills in phase 7 and 8 (Fig 5). In phase 4 slightly above normal rainfall is evident over southwest quarter while slightly below normal rainfall is obvious elsewhere..

For BSISO2 widespread positive rainfall anomalies is evident only in phase 1. During Phase 2, the country was nearly divided into two halves of opposite rainfall anomalies with positive anomalies over southern western part and negative anomalies elsewhere (Fig. 6). Enhancement of positive rainfall anomalies over western slopes of central hills is also evident in phase 2. Phase 3 and 4 are similar to phase 2 with weakening of wet conditions over southwest quarter and strengthening of dry conditions elsewhere. Enhancement of negative rainfall anomalies over Southwest quarter is also evident in phase 6 and 7. Widespread dry conditions can be seen in phase 5 with slightly wet conditions along western and southern coasts.

### Summary

The impact of the MJO on intra-seasonal rainfall variability during Southwest monsoon in Sri Lanka is examined using 30 years of data from 1981–2010. Composites of daily rainfall anomalies are constructed for each of the eight strong MJO phases using Real-time multivariate MJO index<sup>14</sup> and daily rainfall data of 24 stations in Sri Lanka.

To investigate the influence of the Northward propagating ISO on rainfall in Sri Lanka, composites are constructed for each of the eight phases of the BSISO1 and BSISO2<sup>15</sup> during the SWM season. BSISO 1 represents the canonical northward propagating variability that often occurs in conjunction with the eastward MJO with quasi-oscillating periods of 30-60 days and BSISO 2 represents the northward and northwestward propagating variability with periods of 10-30 days existing primarily during the pre-monsoon and monsoon onset season. For BSISO1, positive rainfall anomalies are evident from phase 1 to 3 and negative rainfall anomalies are evident from phase 5 to 7. Widespread positive rainfall anomalies are apparent in phase 1 and widespread negative rainfall anomalies are evident in phase 5

of BSISO2. Enhanced rainfall from phases 2 to 3 and suppressed rainfall from phases 6 to 7 are evident over the Southwest quarter for BSISO2.

As a major source of global predictability on the extended range time scale, better understanding of the impact of MJO and BSISO could potentially improve extended range forecasts of week-two and beyond, particularly when there is an on-going MJO or BSISO event. Numerical and empirical model experiments have shown the potential predictability of the MJO with considerable skill at lead times up to 2–3 weeks<sup>16-18</sup>. Further APEC Climate Center (APCC), provides BSISO predictions 2-3 weeks in advance. In the context of extended-range forecasting, the MJO as well as BSISO composites, discussed above can be used to predict rainfall variability if the future state of the MJO and BSISO is known. The composite maps developed for SWM season in this study provides actionable information for aid decision making within climate sensitive sectors such as agriculture, energy, water resource management, disaster risk management and health.

Although these results go a long way toward explaining a portion of the intraseasonal variability in SWM rainfall over Sri Lanka, it is important to note that the results presented only indicate the average influence of multiple MJO events; given that no MJO event is the same, the impact of any individual event, if it could be determined, would differ from that shown and may be even larger and, perhaps, more predictable.

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