# Modulation of Diurnal Rainfall Cycle by BSISO during Boreal Summer over western part of Indonesia and Southeast Asia

**Donaldi Permana**[1*], Nurdeka Hidayanto[1], Rahmat Triyono[1]

[1]**Center for Standardization Instrument (PSI MKG), Indonesian Agency for Meteorology, Climatology and Geophysics [BMKG]**

*Contact : donaldi.permana@bmkg.go.id

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## Abstract

The Boreal Summer Intraseasonal Oscillation (BSISO) is the dominant mode of intraseasonal variability in tropical rainfall on the large scale during May - September (MJJAS). The characteristic of the BSISO during its propagation through the tropical Asia has always been a challenge, particularly the modulation of diurnal rainfall cycle (DRC) during different BSISO phases over western part of Indonesia and Southeast Asia (SEA). Aiming to investigate the modulation of diurnal rainfall cycle by BSISO during MJJAS (boreal summer) in Western Indonesia, remote sensing derived rainfall data GPM IMERGv07 Final Run, Half-Hourly during MJJAS from 2010 to 2023 (2028 days; 14 years) with spatial resolution 0.1° have been utilized.The results suggest the existing interaction between BSISO and diurnal rainfall cycle at western Indonesia and SEA. Typically, high precipitation rates occurs varyingly between afternoon and midnight. The further inland, high precipitation rates shifts to between night and early morning (particularly, over Borneo). In Sumatra and parts of Borneo, hourly precipitation enhanced (suppressed) during BSISO phase 1 - 3 (5 - 7) by ~2-folds. At eastern Borneo, hourly precipitation enhanced (suppressed) during phase 4 - 6 (1 - 3), particularly between night and early morning. This results could benefit forecasters in understanding the interaction between BSISO to diurnal rainfall cycle during regional extreme precipitation events at subseasonal to seasonal (S2S) time scale.

## Introduction

The Boreal Summer Intraseasonal Oscillation (BSISO) is a dominant mode of atmospheric variability in the tropics during the boreal summer months (May-October). It is characterized by a northward and northwestward propagating pattern of convection and circulation on a **30 - 60 day** (**BSISO1**) and biweekly (BSISO2) timescale. The BSISO significantly influences regional weather patterns, affecting monsoon onsets [1], active/break phases [2], and seasonal rainfall totals [3]. Its predictable nature makes it a key source for subseasonal climate predictability for both precipitation and extratropical atmospheric circulation [4,5,6]. While prior work establishes these large-scale influences, the modulation of finer-scale phenomena like the diurnal rainfall cycle (DRC) is less understood. This study addresses that gap by analyzing the impact of BSISO on hourly rainfall patterns in western Indonesia and Southeast Asia. Understanding its influence on smaller-scale phenomena, like the diurnal cycle of rainfall, is crucial for improving weather forecasts.

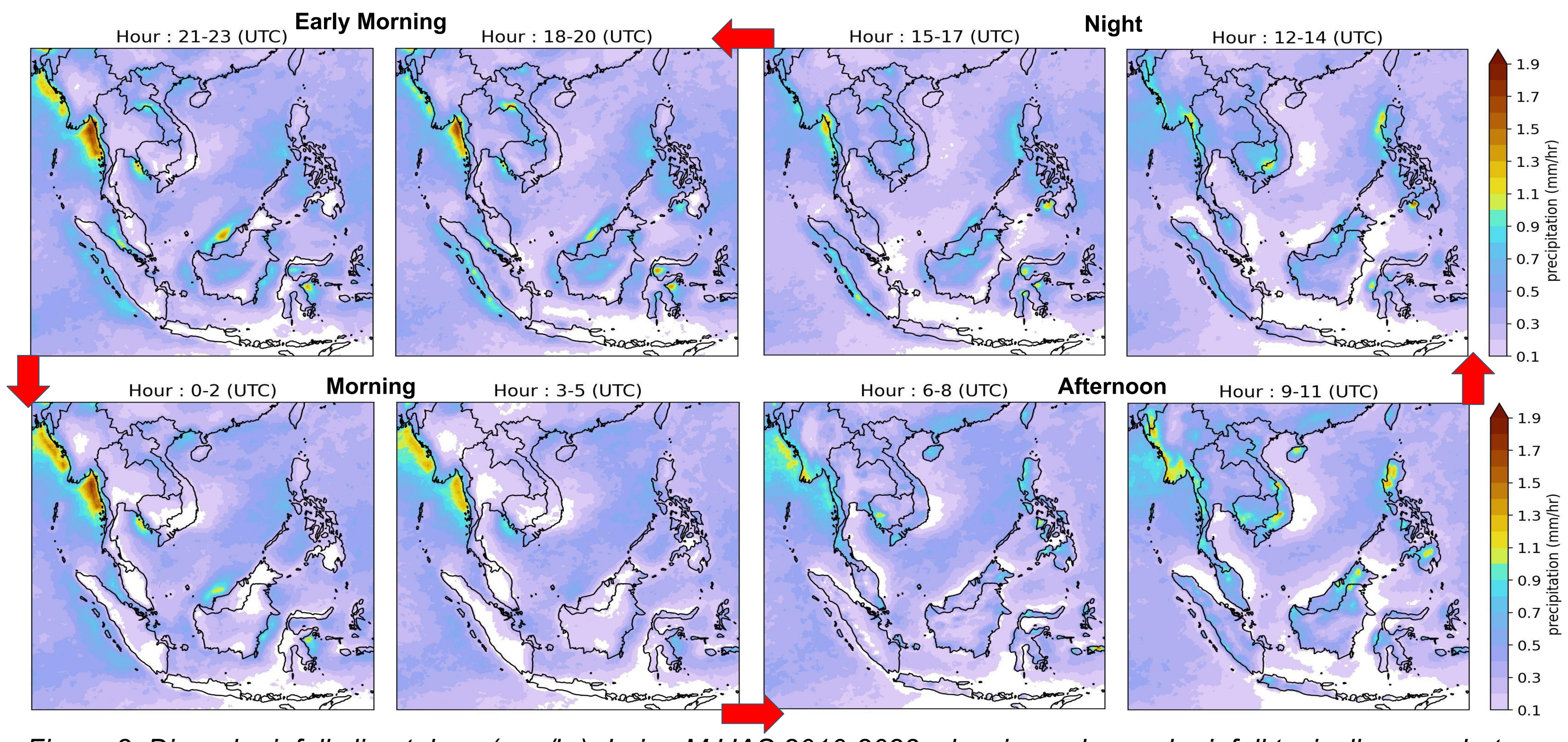


*Figure 2. Diurnal rainfall climatology (mm/hr) during MJJAS 2010-2023, showing enhanced rainfall typically occur between the afternoon and midnight, shifting to later at early morning further inland.*

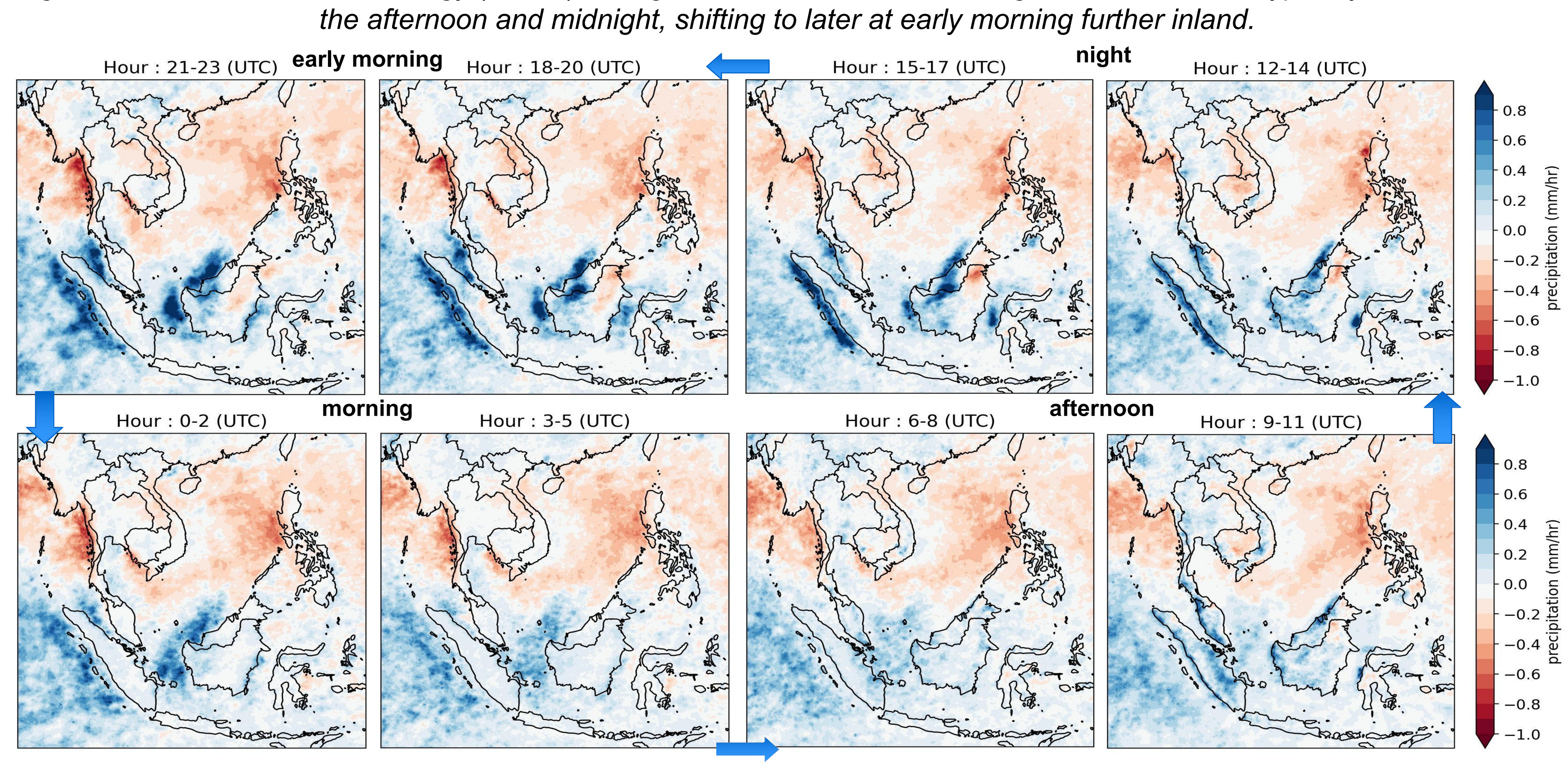


*Figure 3. Diurnal rainfall anomalies (mm/hr) during **BSISO1 phase 2** (n = 179), showing enhanced rainfall over Sumatra and the Malay Peninsula, particularly in between the afternoon (9-11 UTC) and night (18-20 UTC).*

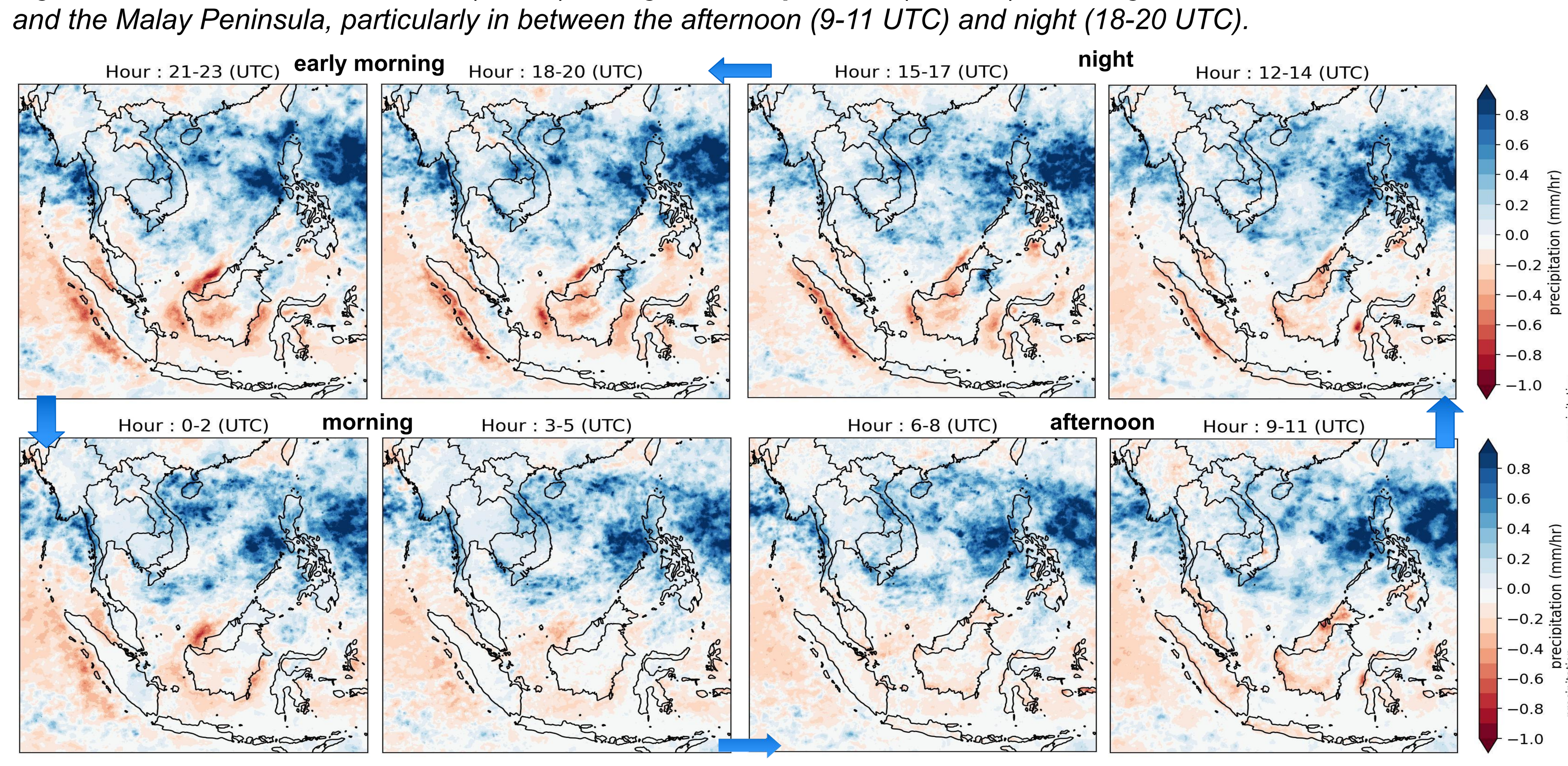


*Figure 4. Diurnal rainfall anomalies (mm/hr) during **BSISO1 phase 6** (n = 111), showing suppressed rainfall over Sumatra and the Malay Peninsula, particularly in between the afternoon (9 - 11 UTC) and night (18 - 20 UTC).*

## Data and Methods

- Half-hourly, 0.1° resolution **rainfall data** from the GPM IMERGv07 Final Run [7] product was used for the boreal summer seasons (MJJAS) from 2010 to 2023 (May 2011, Sep 2012, Jul 2015, Jul 2017 are excluded).
- **BSISO Indices:** The phase and amplitude data for **BSISO1** and BSISO2 were obtained from the APCC (https://download.apcc21.org/BSISO/BSISO.INDEX.NORM.LY.data) [8].
- The MJJAS climatological seasonal mean for each hour was subtracted from hourly rainfall data to generate **deseasonalized** diurnal rainfall anomalies. The diurnal rainfall anomalies for **strong (amplitude ≥ 1.0) BSISO1** phases were **composited**. For extreme rainfall analysis, the percentage change in the 95th percentile (p95) of rainfall was calculated for each BSISO phase.

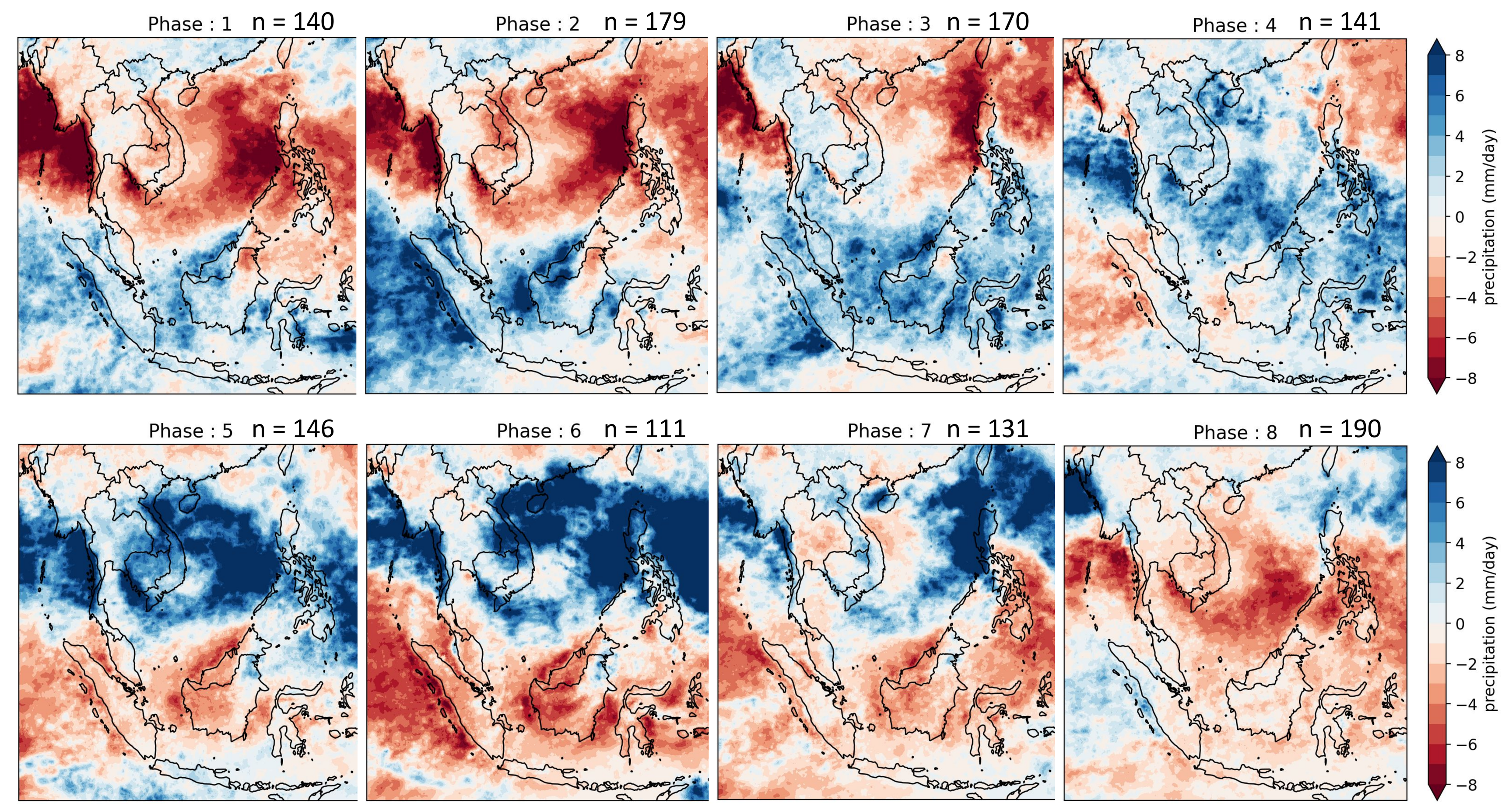


*Figure 1. Mean rainfall anomalies (mm/day) during MJJAS 2010-2023 at each **BSISO1** phase.*

## Results and Discussion

The **BSISO1** demonstrates a strong modulation of both mean daily rainfall and the diurnal rainfall cycle across Indonesia. **Impact on Mean and Extreme Rainfall:** During phases 1 - 3, a positive rainfall anomaly is observed over Sumatra and western/southern Kalimantan. Conversely, phases 5 - 7 show the reverse pattern, with widespread negative rainfall anomalies (Fig.1). This directly impacts the likelihood of extreme weather. In phases 1 - 3, the probability of extreme rainfall (p95) increases by **10% to over 120%** across Sumatra, West Kalimantan, and West Java (not shown). **Modulation of the Diurnal Cycle:** The **BSISO1** not only changes rainfall amounts but also its daily timing. While peak rainfall climatologically occurs between afternoon and midnight (Fig. 2), its intensity is significantly altered by the **BSISO1**.

- **Phases 1 - 3 (Enhanced Convection):** Hourly precipitation is enhanced by approximately two-fold over Sumatra and parts of Borneo (Fig. 3).
- **Phases 5 - 7 (Suppressed Convection):** Hourly precipitation is suppressed in the same regions (Fig. 4).
- Further inland in Borneo, the timing of peak rainfall shifts towards the midnight and early morning. In east coast of Borneo, the rainfall peak in the morning. In northeastern Borneo, there are two peaks with enhancement during phases 4 - 6.

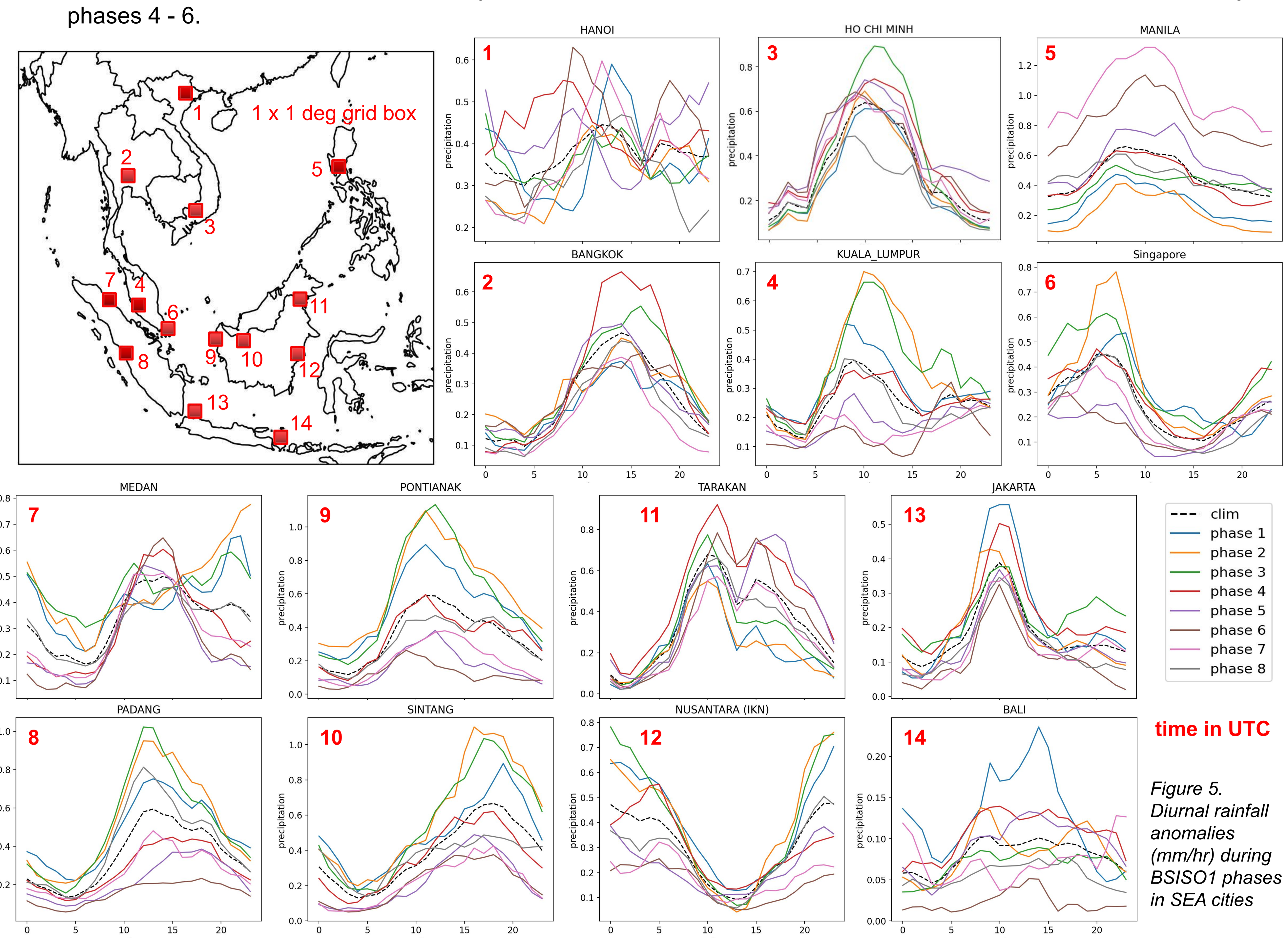


*Figure 5. Diurnal rainfall anomalies (mm/hr) during BSISO1 phases in SEA cities*

## Conclusions

This study confirms a significant interaction between the **BSISO1** and the diurnal rainfall cycle in western Indonesia. **High precipitation rates** typically occur between the afternoon and midnight, shifting to later at early morning further inland. **BSISO1 phases 1-3 enhance** hourly precipitation and the risk of extremes in Sumatra and parts of Borneo, while **phases 5 - 7 cause suppression**. **BSISO1 alters rainfall peak timing** from **night** to **morning** during **phases 1 - 3** in **Medan**. For example in Medan. **Northeastern Borneo** experiences enhanced rainfall during **phases 4 - 6**, particularly at night. This information can directly benefit forecasters by providing a framework for anticipating shifts in daily rainfall patterns and the likelihood of extreme events on subseasonal timescales.

**References**

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