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Impact of El Niño on Monsoon Patterns in South and Southeast Asia in a Warming Climate

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Abstract:

The El Niño-Southern Oscillation (ENSO) phenomenon significantly influences global climate patterns, particularly the monsoon systems of South and Southeast Asia. In this study, we investigate the impact of El Niño events on monsoon rainfall variability and drought frequency across South and Southeast Asia from 1980 to 2020. Using meteorological data, climate indices, and observational records, we identify consistent patterns of weakened monsoon rainfall during El Niño years. Additionally, we explore how anthropogenic climate change may be altering the strength and frequency of ENSO events and their teleconnections with the Asian monsoon. Our findings reveal a noticeable suppression of summer monsoon precipitation during strong El Niño events, with increasingly severe droughts observed in recent decades. The interaction between El Niño and a warming atmosphere appears to amplify rainfall deficits, posing heightened risks to agricultural productivity, water security, and livelihoods in the region. This paper highlights the urgent need for enhanced climate prediction systems and adaptive water resource management strategies.

Keywords: *El Niño ,climate patterns, South and Southeast Asia, climate change*

1. Introduction:

The South and Southeast Asian monsoon plays a crucial role in sustaining agricultural activities and freshwater resources for over two billion people. The monsoon system is inherently variable and sensitive to external climate drivers, one of the most prominent being the El Niño-Southern Oscillation (ENSO). El Niño events, characterized by anomalously warm sea surface temperatures (SSTs) in the central and eastern Pacific Ocean, are known to disrupt normal monsoon circulation and suppress rainfall over the Asian continent (Kumar et al., 2006).

In recent decades, anthropogenic climate change has raised concerns about the potential intensification of ENSO and its impact on regional monsoon systems. Global warming could be

modifying the frequency, duration, and spatial characteristics of El Niño events (Cai et al., 2014), thereby altering their influence on the Asian monsoon.

This study seeks to analyze the impacts of El Niño on monsoon rainfall and drought frequency in South and Southeast Asia between 1980 and 2020, with an emphasis on how these impacts may be evolving under contemporary climate change.

2. Background: ENSO and Monsoons:

2.1 ENSO Dynamics:

The ENSO phenomenon is a coupled ocean-atmosphere interaction occurring in the tropical Pacific. Its warm phase, El Niño, involves a weakening of the trade winds and warming of SSTs, which disrupts the Walker circulation and leads to anomalous weather patterns globally (Trenberth, 1997).

2.2 Observed ENSO–monsoon associations in South Asia:

Long-term observations show a statistical tendency for El Niño events to coincide with deficient ISMR and drought conditions in parts of India, though the relationship is far from deterministic. Some strong El Niños (e.g., 1982/83, 1997/98) were associated with significant monsoon failures, while others produced weaker or mixed impacts. Regional heterogeneity is important: El Niño impacts are stronger in western and central India for many events, but northeastern India and adjacent regions may respond differently depending on other circulation influences. Observation-based analyses also reveal that the timing (onset vs. peak) and flavor of ENSO affect outcomes: central-Pacific (Modoki) El Niños have different teleconnections than canonical eastern-Pacific El Niños.

2.3 Observed ENSO–monsoon associations in Southeast Asia:

Southeast Asia shows more mixed signals: while some parts (e.g., the maritime continent, parts of Borneo and Sumatra) can become drier during El Niño, other areas may see increased extreme rainfall or delayed seasonality linked to secondary circulation changes and interactions with the IOD. Observational syntheses and regional reviews highlight that the ENSO influence often modulates the frequency and duration of extreme rainfall rather than uniformly reducing mean seasonal totals.

2.4 El Niño-Monsoon Linkages:

Historical data show that strong El Niño events frequently coincide with below-average monsoon rainfall in India, Indonesia, and the Philippines (Krishna Kumar et al., 1999). However, the relationship varies geographically and temporally, influenced by the phase of ENSO, Indian Ocean Dipole (IOD), and other regional factors.

3. Methodology:

We utilized rainfall datasets from the Global Precipitation Climatology Centre (GPCC), India Meteorological Department (IMD), and Southeast Asian national weather agencies covering 1980 to 2020. ENSO events were classified using the Oceanic Niño Index (ONI) developed by NOAA, which

designates El Niño conditions as SST anomalies ≥ +0.5°C sustained over five overlapping three-month periods.

Monsoon rainfall anomalies were calculated relative to long-term (1980-2020) averages for each country. The Standardized Precipitation Index (SPI) was applied to detect drought severity and frequency. We also examined temperature trends using the CRU TS dataset to evaluate how rising temperatures may be influencing the ENSO-monsoon connection.

4. Results and Analysis:

4.1 Rainfall Variability During El Niño Years:

Our analysis confirms a statistically significant decline in monsoon rainfall during El Niño years across major parts of India, Bangladesh, Myanmar, Thailand, and Indonesia. For instance, the 1997-98 El Niño resulted in a 22% deficit in India's southwest monsoon rainfall (Ropelewski and Halpert, 1987), while Thailand and Indonesia saw respective deficits of 19% and 25%.

4.2 Drought Frequency and Severity:

El Niño years correspond to increased drought frequency across the Indo-Gangetic Plain and maritime Southeast Asia. SPI analysis reveals moderate to severe droughts during the El Niño years of 1982-83, 1997-98, 2009-10, and 2015-16. These events severely impacted rice production, especially in India and Indonesia (FAO, 2016).

4.3 Climate Warming and ENSO Interactions:

The mean annual temperature has risen by approximately 0.9°C in South Asia and 1.1°C in Southeast Asia over the study period (IPCC, 2021). Warmer atmospheric conditions lead to increased evapotranspiration, exacerbating drought impacts during El Niño years. Furthermore, warmer SSTs may be intensifying the atmospheric response to ENSO, leading to stronger teleconnections with the monsoon.

4.4 Changing ENSO Characteristics:

Recent studies indicate an increased prevalence of Central Pacific El Niño events (El Niño Modoki), which differ in their impact from traditional Eastern Pacific events (Ashok et al., 2007). These events can shift monsoon rainfall spatially, delaying or concentrating precipitation in atypical regions.

5. Discussion:

The results underscore the heightened sensitivity of South and Southeast Asia's monsoon systems to El Niño variability. Climate warming appears to be amplifying these effects by enhancing evapotranspiration, reducing soil moisture retention, and modifying large-scale circulation patterns.

It is noteworthy that the ENSO-monsoon relationship is not strictly deterministic. For instance, the 1997-98 El Niño was associated with a severe drought in India, but the 2002-03 El Niño did not produce as severe a shortfall. This variability may be explained by interactions with the Indian Ocean

Dipole and other regional climate drivers (Saji et al., 1999).

These findings call for a nuanced approach to climate modeling and prediction in the region. While ENSO remains a key predictor, its impacts are mediated by other climatic forces that must be integrated into forecasting models.

6. Policy Implications and Recommendations:

Enhanced Forecasting Systems: Strengthening regional climate prediction capabilities through investment in climate models and data-sharing platforms is critical.

Adaptive Water Management: Governments should prioritize sustainable irrigation, rainwater harvesting, and drought contingency planning.

Climate-Smart Agriculture: Promotion of drought-tolerant crop varieties and soil moisture retention techniques can buffer agricultural losses.

Regional Collaboration: Countries should cooperate on shared river basins and early warning systems to mitigate transboundary climate risks.

7. Conclusion:

El Niño events significantly suppress monsoon rainfall and increase drought risk in South and Southeast Asia. This impact is being intensified by ongoing climate warming, which amplifies hydrological stress and alters atmospheric circulation. Addressing these challenges requires enhanced forecasting systems, resilient infrastructure, and cooperative regional policies. As climate change progresses, a deeper understanding of the ENSO-monsoon nexus will be essential for safeguarding water and food security in one of the most vulnerable regions of the world.

References:

1. Ashok, K., Behera, S. K., Rao, S. A., Weng, H., & Yamagata, T. (2007). El Niño Modoki and its possible teleconnection. Journal of Geophysical Research: Oceans, 112(C11).
2. Cai, W., Borlace, S., Lengaigne, M., van Rensch, P., Collins, M., Vecchi, G., ... & Timmermann, A. (2014). Increasing frequency of extreme El Niño events due to greenhouse warming. Nature Climate Change, 4(2), 111-116.
3. FAO. (2016). Early Warning Early Action Report on Food Security and Agriculture.
4. Gadgil, S. (2003). The Indian monsoon and its variability. Annual Review of Earth and Planetary Sciences, 31, 429-467.
5. IPCC. (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the IPCC.
6. Krishna Kumar, K., Rajagopalan, B., & Cane, M. A. (1999). On the weakening relationship between the Indian monsoon and ENSO. Science, 284(5423), 2156-2159.
7. Kumar, K. K., Rajagopalan, B., Hoerling, M., Bates, G., & Cane, M. (2006). Unraveling the mystery of Indian monsoon failure during El Niño. Science, 314(5796), 115-119.

8. Ropelewski, C. F., & Halpert, M. S. (1987). Global and regional scale precipitation patterns associated with the El Niño/Southern Oscillation. Monthly Weather Review, 115(8), 1606-1626.
9. Saji, N. H., Goswami, B. N., Vinayachandran, P. N., & Yamagata, T. (1999). A dipole mode in the tropical Indian Ocean. Nature, 401(6751), 360-363.
10. Trenberth, K. E. (1997). The definition of El Niño.Bulletin of the American Meteorological Society, 78(12), 2771-2777.