

A REVIEW OF THE IMPACT OF EL NIÑO–SOUTHERN OSCILLATION (ENSO) AND ADAPTATION STRATEGIES ON WEATHER AND CLIMATE IN MALAYSIA

MENYINGKAP KESAN EL NIÑO–SOUTHERN OSCILLATION (ENSO) TERHADAP CUACA DAN IKLIM SERTA STRATEGI ADAPTASI DI MALAYSIA

MOHD HASHIQ HASHIM & MOHD HAIRY IBRAHIM

Jabatan Geografi dan Alam Sekitar, Fakulti Sains Kemanusiaan,
Universiti Pendidikan Sultan Idris, 35900 Tanjung Malim, Perak.

Corresponding author: hashiqhashim94@gmail.com

Received: 7th July 2025 Accepted: 6th September 2025

Abstract

This article reviews the influence of the El Niño–Southern Oscillation (ENSO) phenomenon on weather and climate patterns in Malaysia, with a focus on temperature and rainfall variability. A literature review approach was employed, analyzing ten selected studies on ENSO in the Malaysian context. Findings indicate that El Niño is generally associated with increased temperatures and reduced rainfall, while La Niña tends to cause heavier rainfall and impacts on marine activities. Various methodologies, including statistical, correlation, and spatial analyses, were used to evaluate ENSO's effects. Based on the review, the article also proposes several adaptation and mitigation strategies, such as enhanced climate forecasting systems, disaster risk management, and strengthened climate policy frameworks. This study aims to provide a more focused overview of ENSO and support national responses to extreme climate events in Malaysia.

Keywords: El Niño–Southern Oscillation, Malaysia, weather variability, adaptation, mitigation

Abstrak

Artikel ini meninjau pengaruh fenomena El Niño–Southern Oscillation (ENSO) terhadap cuaca dan iklim di Malaysia, khususnya perubahan suhu dan taburan hujan. Kajian menggunakan pendekatan tinjauan literatur terhadap sepuluh artikel terpilih berkaitan ENSO dalam konteks Malaysia. Dapatan menunjukkan fasa El Niño lazimnya dikaitkan dengan peningkatan suhu dan pengurangan hujan, manakala La Niña menyebabkan hujan lebat serta impak terhadap aktiviti marin. Pelbagai metodologi seperti analisis statistik, korelasi dan spatial digunakan untuk menilai kesan fenomena ini. Berdasarkan sorotan tersebut, artikel ini turut mengemukakan cadangan strategi adaptasi dan mitigasi seperti peningkatan sistem ramalan iklim, pengurusan bencana, dan pemerkasaan dasar perubahan iklim. Diharapkan artikel ini dapat menyumbang kepada pemahaman yang lebih berfokus serta membantu perancangan respons terhadap perubahan iklim ekstrem di Malaysia.

Kata Kunci: El Niño–Southern Oscillation, Malaysia, variasi cuaca, adaptasi, mitigasi

INTRODUCTION

The El Niño–Southern Oscillation (ENSO) is a natural, large-scale climate phenomenon that originates in the tropical Pacific Ocean (McPhaden et al. 2020). Generally, this phenomenon is closely linked to changes in sea surface temperature (Philander 1990). According to the National Oceanic and Atmospheric Administration (NOAA), ENSO consists of three main phases: El Niño, La Niña,

and the neutral phase. El Niño refers to an abnormal warming of sea surface temperatures in the central and eastern Pacific, while La Niña is characterized by a cooling of sea surface temperatures in the same region. The neutral phase refers to normal sea surface temperature conditions. All three phases have the capacity to significantly influence atmospheric circulation systems and alter global weather patterns, which in turn may trigger extreme weather events in certain parts of the world (Yu et al. 2017).

The ENSO phenomenon is identified through several key climate indices that measure changes in sea surface temperature and atmospheric pressure across the tropical Pacific region. Among the most commonly used is the Oceanic Niño Index (ONI), which is based on sea surface temperature (SST) and serves as a primary parameter in determining the presence of El Niño or La Niña phases. In addition, the Southern Oscillation Index (SOI) is another important ENSO indicator, calculated by comparing atmospheric pressure differences between two locations: Darwin, Australia, and Tahiti, French Polynesia. Previous studies, including those by Bjerknes (1969), Rasmussen and Carpenter (1982), and Wyrki (1985), have shown that sea surface temperature plays a dominant role in identifying and understanding ENSO phase transitions. Monitoring zones such as Niño1, Niño2, Niño3, and Niño4 are used to obtain more detailed information on oceanic conditions in the tropical Pacific. Based on the index values derived from these parameters, ENSO events are classified into four levels: weak, moderate, strong, and super, each indicating different degrees of climatic impact.

The El Niño phase is a climatic phenomenon that can influence weather patterns across various regions, including Malaysia. This phenomenon occurs along the equatorial belt and is centered in the eastern Pacific Ocean, characterized by a temporary warming of sea surface temperatures. During the El Niño phase, atmospheric pressure in the eastern Pacific becomes low, causing air movement from high-pressure areas such as Malaysia toward the low-pressure zone over the ocean. This shift disrupts local atmospheric systems, leading to increased temperatures and reduced rainfall in Malaysia. These changes often result in extreme weather events such as droughts, heavy rainfall, and heatwaves. Therefore, conducting a systematic literature review is crucial to establish strong evidence regarding the influence of ENSO on Malaysia's weather patterns.

DEFINITION AND CONCEPT

El Niño Southern Oscillation

The El Niño–Southern Oscillation (ENSO) is a natural phenomenon that occurs periodically every three to seven years, yet it has a significant impact on global weather patterns during both the El Niño and La Niña phases. The most visible effects include extreme heat and floods around the world during these events. According to Ahrens (2015), ENSO is caused by interactions between the atmosphere and the ocean, which are related to global wind patterns and surface ocean currents. The El Niño phase, in particular, has a negative impact on aquatic life and marine vegetation, disrupting marine ecosystems. Neelin (2011) also emphasized that the tropical Pacific Ocean and atmospheric conditions are key factors in determining ENSO phases. Accurate identification of El Niño and La Niña phases requires a deep understanding of the interaction between atmospheric and oceanic elements in order to produce more reliable and realistic forecasts (Ahrens 2015; Neelin 2011).

El Niño Phase

El Niño is one of the phases that occurs during the ENSO phenomenon and is often associated with hot or drought-like conditions. Generally, El Niño is known as the warming phase, referring to the increase in sea surface temperatures in the equatorial Pacific region. According to Philander (1989), the El Niño phase can be identified based on sea surface temperature and rainfall distribution in the central and eastern tropical Pacific. El Niño is classified into four intensity levels: strong, moderate, weak, and very weak (Quinn et al. 1978). However, recent research has found that an extreme El Niño category exists, which is influenced by global warming or the greenhouse effect (Cai et al. 2014). Glantz (1996) even suggested that the term “El Niño” should be included in dictionaries as a standard reference term.

La Niña Phase

La Niña is one of the phases that occurs within the ENSO phenomenon and is relatively opposite to the El Niño phase, as it is better known as the cooling phase in the tropical Pacific Ocean. This condition forms when strong trade winds push cold water from the ocean depths to the surface, a process known as upwelling (Wang & Picaut 2004). This process leads to a decrease in sea surface temperatures, which in turn affects the balance between the atmosphere and the ocean. According to Takahashi and Hasegawa (2018), the La Niña phase has a significant impact on temperature changes, rainfall distribution patterns, and the occurrence of tropical storms in various regions, including tropical and subtropical areas.

LITERATURE REVIEW

The El Niño–Southern Oscillation can last for several months or up to a year, depending on the strength and duration of the phase (McPhaden 2006; McPhaden 2020). Scientific studies have shown that ENSO can cause devastating droughts, storms, and floods in various regions around the world (Yang et al. 2023). ENSO monitoring areas are divided into four main zones: Niño 1+2, Niño 3, Niño 3.4, and Niño 4, with most studies focusing on Niño 3.4 as the primary region for analysis. According to Yang et al. (2023), nearly 75 percent of the Earth's surface is influenced by ENSO in the form of temperature changes and extreme hydrological conditions. As a result of this disruption, the global water balance is also affected. A study by Guo et al. (2021) found that terrestrial water storage has a significant relationship with ENSO phases, highlighting the substantial impact of the phenomenon on global water resources.

The ENSO Phenomenon in Malaysia

Generally, Malaysia is influenced by two major monsoon systems—the Southwest Monsoon and the Northeast Monsoon—which together shape dynamic weather patterns through variations in rainfall and temperature throughout the year. However, the El Niño and La Niña phases, as part of the ENSO phenomenon, have the potential to alter and influence atmospheric conditions during both monsoon seasons. An early study by Boon-Cheang (1993), supported by Juneng and Tangang (2007), showed that the El Niño phase tends to disrupt the Northeast Monsoon, particularly by reducing rainfall distribution. In contrast, the La Niña phase tends to intensify both the Northeast and Southwest Monsoons, as evidenced by increased heavy rainfall and occurrences of flash floods in several regions across Malaysia.

According to Mou et al. (2021), there is a significant relationship between temperature in Malaysia and the El Niño Southern Oscillation (ENSO) phenomenon, with notable increases in surface temperature recorded during the El Niño phase. Meanwhile, a study by Tangang (2017) showed that extreme rainfall tends to occur during the La Niña phase, while total rainfall decreases significantly during El Niño, according to the analysis of rainfall distribution data in Malaysia. Based on findings from previous researchers, it can be stated that ENSO is closely related to weather and climate patterns in Malaysia. However, as meteorological systems are complex and dynamic, a comprehensive evaluation of atmospheric and oceanic interactions is essential to gain a more accurate understanding of the actual impacts of this phenomenon.

A study conducted by Ricky and Oliver (2021) found that El Niño can enhance the urban heat island effect due to the increase in temperature in urban areas. The study utilized satellite data and the Oceanic Niño Index (ONI) to analyze temperature variation patterns, demonstrating a significant relationship between El Niño and rising temperatures. In contrast, a study by Mahmud and Ahmad (2018) focused more on the impact of the ENSO phenomenon on air quality in Malaysia, which is affected by dry weather conditions. Their findings revealed that the ENSO index shows a negative correlation with rainfall distribution, which indirectly contributes to the deterioration of air quality due to reduced humidity.

SUMMARY OF SELECTED STUDIES

A targeted literature search was conducted to identify peer-reviewed studies that focused on the impact of El Niño–Southern Oscillation (ENSO) on weather and climate in Malaysia. The selection emphasized studies published between 1993 and 2024, with priority given to those employing quantitative methodologies such as statistical analyses, satellite-derived spatial data, or climate indices like ONI and SOI. Studies were also selected based on their relevance to key climatic parameters, including temperature, precipitation, and extreme weather events. A total of twelve articles were reviewed, most of which were conducted within the Malaysian context to ensure regional specificity and relevance to national adaptation strategies. Table 1 presents a summary of previous research related to ENSO in Malaysia. These sources were synthesized based on the approach by Kamal Azmi et al. (2021), which emphasizes both methodology and findings in a consolidated table format.

Table 1. Summary of Selected Studies on ENSO in Malaysia

No	Author	Methodology	Findings
1	Boon-Khean (1993)	Rainfall variability and statistical analysis – identifying years with very high and low rainfall.	The study showed that most El Niño years were associated with below-median rainfall, while La Niña years had above-median rainfall at most stations in Malaysia. ENSO had a stronger influence in East Malaysia than in Peninsular Malaysia.
2	Tangang et al. (2017)	Extreme weather index analysis – including aspects of rainfall duration, frequency, and intensity.	The study focused on seasonal variations in extreme rainfall associated with ENSO in Malaysia, finding that extreme rainfall tends to increase during La Niña and decrease during El Niño, depending on season and location.
3	Mahmud (2020)	Statistical analysis – applied to rainfall, Indian Ocean Dipole (IOD), and ENSO data.	The study examined the influence of El Niño and the Indian Ocean Dipole on rainfall in Malaysia, finding that both phenomena affect the amount of rainfall received.
4	Mahmud & Ahmad (2018)	Statistical analysis – using correlation analysis between the Southern Oscillation Index (SOI), rainfall data, and air quality.	The study examined El Niño event patterns and their relationship with rainfall and the effects of dry conditions on air quality in Malaysia. It found a weak negative correlation between the ENSO index and rainfall distribution.
5	Abdullah et al. (2015)	Harmonic analysis – using tidal and sea level data to assess ENSO impacts.	The study identified variations in sea level and tidal behavior along the Malaysian coast during El Niño/La Niña events, showing significant changes in tidal patterns that could affect marine activities.
6	Daud et al. (2019)	Spatial analysis – using satellite data to analyze ENSO effects on upwelling.	The study examined ENSO dynamics on upwelling and thermal front zones along the east coast of Peninsular Malaysia, showing changes in sea surface temperature associated with ENSO.
7	Mou et al. (2021)	Statistical analysis – using Mann-Kendall test and correlation to assess temperature trends during ENSO phases.	The study assessed extreme temperature variations in Malaysia and their link to ENSO, showing significant surface temperature increases, especially in Peninsular Malaysia.
8	Kemarau & Eboy (2021)	Statistical analysis – using correlation and regression between ENSO indices and surface temperature changes.	The study investigated the impact of ENSO on urban heat island formation in Kuching, Sarawak, showing that El Niño intensifies urban heat through rising temperatures.

9	Kemarau et al. (2024)	Spatial analysis – using Landsat satellite data converted into index format.	The study evaluated the effects of El Niño, Indian Ocean Dipole, and Madden–Julian Oscillation on land surface temperature in Kuching, Sarawak, showing significant temperature increases during El Niño events.
10	Richard & Walsh (2018)	Statistical analysis – using regression to assess ENSO's impact on rainfall.	The study analyzed the influence of ENSO on boreal winter rainfall in Peninsular Malaysia, showing a significant decrease during El Niño and increased rainfall during La Niña phases.
11	Zakaria et al. (2024)	Spatio-temporal drought analysis using SPI index derived from CHIRPS rainfall dataset (1982–2021), with focus on ENSO and positive Indian Ocean Dipole interaction.	El Niño significantly increases drought frequency and severity, especially when coupled with pIOD; Northeastern Peninsular Malaysia shows rising drought trends.
12	Tangang et al. (2017)	Analysis of precipitation extremes using indices from the Expert Team on Climate Change Detection and Indices (ETCCDI); based on daily rainfall data from 1971–2013; focused on El Niño years	El Niño significantly reduces annual and extreme rainfall indices in Peninsular and East Malaysia, especially during northeast monsoon; consistent weakening of wet spells observed during El Niño years

The review of studies in this paper shows that there are variations in terms of approach, scope, and findings between one study and another. Although there are similarities in identifying temperature increases during El Niño and higher rainfall during La Niña, the analyses used differ in terms of depth and methodology. Most studies focus on historical data without integrating forecasting models, and research conducted in East Malaysia remains limited. This highlights the need for more comprehensive and comparative studies across different regions.

DISCUSSIONS

Based on the review of ten selected articles, it was found that researchers have used a variety of methodologies to analyze the impact of the ENSO phenomenon on weather and climate in Malaysia. A majority of researchers have adopted statistical analysis approaches to determine the relationship and influence of ENSO on climatic parameters such as temperature and rainfall, as demonstrated by Boon-Kheang (1993), Mahmud (2020), Mahmud and Ahmad (2018), Mou et al. (2021), Kemarau and Eboy (2021), and Richard and Walsh (2018). In addition, some researchers have utilized spatial analysis methods using satellite imagery to provide a more detailed visual and spatial representation of ENSO's impact, as seen in the research by Daud et al. (2019) and Kemarau et al. (2024). According to Fischer (2015), spatial analysis plays an important role in understanding patterns and processes that occur within geographical space.

The findings presented in previous studies show a clear continuity with one another. For example, Boon-Kheang (1993) found that the impact of ENSO is more prominent in East Malaysia. This finding is supported by studies conducted by Kemarau et al. (2024) and Kemarau and Eboy (2021), which reported a significant increase in temperature during El Niño events in Kuching, Sarawak. In contrast, the study by Abdullah et al. (2015) examined tidal patterns along Malaysia's coastal areas and found that ENSO also affects ocean dynamics, which in turn influence marine activities. Meanwhile, studies by Mahmud (2020) as well as Mahmud and Ahmad (2018) emphasized that the El Niño phase leads to reduced rainfall distribution in several parts of Malaysia. However,

Mou et al. (2021) argued that extreme temperatures are linked to surface temperature changes, particularly in Peninsular Malaysia.

Zakaria et al. (2024) also conducted a comprehensive 39-year analysis using the Standardized Precipitation Index (SPI) with high-resolution CHIRPS data. The findings reinforce the dominant role of El Niño in influencing drought conditions across Malaysia and identify regions exhibiting significant drought trends. Also, Tangang et al. (2017) conducted a detailed analysis of precipitation extremes in Malaysia by examining daily rainfall data from 1971 to 2013, their study demonstrated that El Niño events are associated with significant reductions in both annual and extreme rainfall indices across Peninsular and East Malaysia, particularly during the northeast monsoon. The findings provide strong empirical evidence of weakened wet spells during El Niño years, contributing valuable insight into how ENSO influences extreme hydrometeorological events in the Malaysian region. Overall, the findings from previous researchers confirm that the ENSO phenomenon has a significant impact on atmospheric conditions in Malaysia, especially in terms of rainfall distribution and temperature.

Despite the established influence of ENSO on Malaysia's weather patterns, most of the reviewed studies focus solely on historical observations, lacking future-oriented perspectives. The involvement of climate models such as the Coupled Model Intercomparison Project Phase 6 (CMIP6) is notably absent in the Malaysian context. Global studies have projected an increase in the frequency and intensity of extreme El Niño events under warming scenarios (Cai et al. 2018), which may amplify rainfall variability and exacerbate drought or flood risks in Southeast Asia. Therefore, future research should incorporate ensemble model simulations and regional climate downscaling to assess potential ENSO-related risks under different greenhouse gas trajectories. Integrating these projections is vital for long-term adaptation planning and policy development.

ADAPTATION AND MITIGATION STRATEGIES FOR ENSO IN MALAYSIA

Based on findings from previous studies, several adaptation and mitigation strategies have been identified as proactive measures to reduce the impact of the El Niño–Southern Oscillation (ENSO) phenomenon on public well-being. Wan et al. (2024) proposed an innovative approach through geoengineering technology such as marine cloud brightening, which has the potential to reduce the intensity of El Niño by stabilizing sea surface temperatures in the tropical Pacific region. This strategy demonstrates significant potential in mitigating extreme climate impacts through scientifically driven atmospheric intervention. In the context of forecasting and preparedness, Costas et al. (2024) developed a composite forecasting system that integrates various climate parameters to predict El Niño events earlier and more accurately. Such forecasting is crucial for giving sufficient lead time to sectors such as agriculture, water resource management, and public safety to develop effective contingency plans.

Adaptation and mitigation strategies in Malaysia have been outlined through the National Climate Change Policy 2.0, published by the Ministry of Natural Resources and Environmental Sustainability (NRES) in 2024. This policy emphasizes a balance between carbon mitigation efforts and adaptive resilience to climate-related disasters such as droughts and floods associated with the ENSO phenomenon. Among the key strategies outlined are the development of early warning systems based on satellite data and climate indices, the strengthening of local community capacity through climate education programs, and the empowerment of smart technologies in water and agricultural management. These approaches are not only crucial for disaster risk reduction but also support national development in addressing the increasingly complex challenges of climate change.

In addition to local adaptation and mitigation strategies, approaches from regional countries such as Bangladesh offer valuable insights for the development of broader regional frameworks. For example, Islam and Parvez (2020) proposed the AMSELICAB model (Adaptation and Mitigation Strategies on El Niño and La Niña Impact on Coastal Areas in Bangladesh) as a comprehensive framework for integrated coastal zone management. This model emphasizes the need for continued research in developing salinity-tolerant species, the use of economic instruments to reduce adaptation

costs, and the protection of marine biodiversity. Although AMSELICAB has certain limitations, it presents potential as a reference model for regional responses to ENSO impacts. Therefore, Malaysia's long-term adaptation planning could benefit from integrating elements such as coastal zone management, investment in climate-resilient aquaculture research, and socioeconomic impact assessments tailored to vulnerable coastal communities.

CONCLUSION

Overall, the El Niño–Southern Oscillation (ENSO) has been proven to have a significant impact on weather and climate in Malaysia, particularly in terms of temperature changes and rainfall distribution. Findings from various previous studies indicate that the El Niño phase is often associated with increased temperatures and reduced rainfall, leading to extreme weather events such as droughts, while the La Niña phase tends to increase rainfall, which can cause flash floods and changes in atmospheric dynamics. Studies conducted in Malaysia have employed various approaches such as statistical analysis and spatial analysis, supported by satellite data and ENSO indices like ONI and SOI, to develop a more comprehensive understanding of this phenomenon. Therefore, a deep understanding of ENSO is crucial not only from an academic standpoint but also for policy planning and mitigation strategies by relevant agencies, in order to reduce the negative impacts on water resources, agriculture, and public safety.

Based on this literature review, several research gaps have been identified. These include the limited number of long-term studies conducted in East Malaysia, particularly in Sabah and Sarawak, and the need to enhance the integration of local meteorological data with global ENSO forecasting models. In addition, there remains a lack of research on the direct impacts of ENSO on key economic sectors such as agriculture, fisheries, and tourism. Future studies are crucial to evaluate the effectiveness of adaptation strategies at the community level, particularly in areas that are increasingly affected by climate variability.

REFERENCE

- Abdullah, M. H., Mahmud, M. R., & Amat, N. A. 2015. Variations of Sea Level and Tidal Behaviour during El Niño/La Niña: An Example of Malaysian Coastline. *Jurnal Teknologi* 73(5): 1-7.
- Ahrens, C. D. 2015. *Meteorology today: An introduction to weather, climate, and the environment* (11th ed.). Cengage Learning.
- Bjerknes, J. 1969. Atmospheric teleconnections from the equatorial Pacific. *Monthly Weather Review* 97(3): 163–172.
- Boon-Khean Cheang. 1993. Interannual variability of monsoons in Malaysia and its relationship with ENSO. *Earth Planet Science* 102(1): 219-239.
- Cai, W., Borlace, S., Lengaigne, M., van Rensch, P., Collins, M., Vecchi, G., ... & Jin, F.-F. 2014. Increasing frequency of extreme El Niño events due to greenhouse warming. *Nature Climate Change* 4(2): 111–116.
- Cai, W., Wang, G., Dewitte, B. et al. 2018. Increased variability of eastern Pacific El Niño under greenhouse warming. *Nature* 564: 201–206.
- Daud, N. R., Akhir, M. F., & Muslim, A. M. 2019. Dynamic of ENSO towards upwelling and thermal front zone in the east coast of Peninsular Malaysia. *Acta Oceanologica Sinica* 38: 48–60.
- Fischer, Manfred M. 2015. Spatial analysis in geography. Dlm Wright, J. D. (Ed.), *International Encyclopedia of the Social & Behavioral Sciences* (Edisi ke-2, hlm. 317–326). Elsevier.
- Glantz, M. H. 1996. *Currents of change: El Niño's impact on climate and society*. Cambridge University Press.
- Guo, W., Pan, M., Li, H., & Wood, E. F. 2021. Terrestrial water storage variability in a changing climate. *Nature Reviews Earth & Environment* 2(2): 89–105.
- Juneng, L., & Tangang, F. 2007. Level and source of predictability of seasonal rainfall anomalies in Malaysia using canonical correlation analysis. *International Journal of Climatology* 28(1): 1255-1267.
- Kamal Azmi, M. N., Mokhtar, M. B., Yusop, Z., & Shahid, S. 2021. A systematic review of climate variability and extreme weather impacts in Malaysia. *Environmental Research Letters* 16(10): 103003.

- Kemarau, R. A., & Eboy, O. V. 2021. The influence of El Niño Southern Oscillation on urban heat island formation at tropical city: Case of Kuching City, Sarawak. *Geografia: Malaysian Journal of Society and Space* 17(4): 288–304.
- Kemarau, R. A., Boo, W. H., Sakawi, Z., Dambul, R., Suab, S. A., Wan Mohd Jaafar, W. S., Eboy, O. V., & Norzin, M. A. F. 2024. Impact of El Niño, Indian Ocean dipole, and Madden–Julian oscillation on land surface temperature in Kuching City Sarawak, during the periods of 1997/1998 and 2015/2016: A pilot study. *Journal of Water and Climate Change* 15(8): 3702–3723.
- Mahmud, M. 2020. Peristiwa El Nino dan Pengaruh IOD Terhadap Hujan di Malaysia. *e-Bangi: Journal of Social Sciences & Humanities* 17(4): 1–12.
- Mahmud, M., & Ahmad, N. H. 2018. Peristiwa El Nino, keragaman hujan dan potensi Southern Oscillation Index untuk peramalan kualiti udara di Malaysia. *Geografia: Malaysian Journal of Society and Space* 14(2): 13–25.
- National Oceanic and Atmospheric Administration. (n.d.). What is the El Niño–Southern Oscillation (ENSO) cycle? Climate.gov. <https://www.climate.gov/news-features/understanding-climate/climate-variability-el-ni%C3%B1o-and-la-ni%C3%B1a>
- Neelin, J. D. 2011. *Climate change and climate modeling*. Cambridge University Press.
- Mou Leong Tan, Liew Juneng, Fredolin T. Tangang, Jin Xiang Chung, Radin Firdaus R. B. 2021. Changes in temperature extremes and their relationship with ENSO in Malaysia from 1985 to 2018. *International Journal of Climatology* 41(S1): E2564–E2580.
- Philander, S. G. 1990. *El Niño, La Niña, and the Southern Oscillation*. Academic Press.
- Philander, S. G. 1989. El Niño and La Niña: Causes and global consequences. *Earth and Planetary Science Letters* 87(1): 1–10.
- Quinn, W. H., Neal, V. T., & Antunez de Mayolo, S. E. 1978. El Niño occurrences over the past four and a half centuries. *Journal of Geophysical Research* 83(C8): 1571–1574.
- Rasmussen, E. M., & Carpenter, T. H. 1982. Variations in tropical sea surface temperature and surface wind fields associated with the Southern Oscillation/El Niño. *Monthly Weather Review* 110(5): 354–384.
- Richard, S., & Walsh, K. J. E. 2018. The influence of El Niño–Southern Oscillation on boreal winter rainfall over Peninsular Malaysia. *Theoretical and Applied Climatology* 134: 121–138.
- Takahashi, K., & Hasegawa, T. 2018. Impacts of ENSO on the variability of tropical cyclones and rainfall in Southeast Asia. *Progress in Earth and Planetary Science* 5(1): 1–17.
- Tangang, F., Salimun, E., Idin, M., Selaman, N., Syamsuddin, M. F., & Din, J. 2017. Characteristics of precipitation extremes in Malaysia associated with El Niño and La Niña events: Spatial patterns, influence of ENSO and IOD and temporal changes. *International Journal of Climatology* 37(14): 677–693.
- Tangang, F., Farzanmanesh, R., Mirzaei, A., Supari, Salimun, E., Jamaluddin, A. F., & Juneng, L. 2017. Characteristics of extreme rainfall in Malaysia associated with El Niño and La Niña events. *International Journal of Climatology* 37(S1): 696–716.
- Wan, J. S., Fasullo, J. T., Rosenbloom, N., Chen, C.-C. J., & Ricke, K. 2024. Targeted marine cloud brightening can dampen El Niño [Preprint]. arXiv.
- Wang, C., & Picaut, J. 2004. Understanding ENSO physics—A review. In Wang, C., Xie, S.-P., & Carton, J. A. (Eds.), *Earth's climate: The ocean–atmosphere interaction*, hlm. 21–48. American Geophysical Union.
- Yang, S., Li, Y., Lau, K.-M., & Xie, S.-P. 2023. Global hydrological response to ENSO: Extreme droughts and floods. *Nature Reviews Earth & Environment* 4(2): 76–89.
- Zakaria, N. A. B., Tangang, F., Salimun, E., Amirudin, A. A., Juneng, L., & Sulaiman, F. 2024. Spatio-temporal variations and El Niño modulation of meteorological droughts in Malaysia. *International Journal of Climatology* 44(15): 5560–5580.