DRIVERS OF NORTHERN AUSTRALIAN CLIMATE AND WEATHER FOR COTTON PRODUCTION

NORTHERN AUSTRALIA CLIMATE REVIEW 2025

ABSTRACT

Northern Australia is characterised by its highly variable rainfall patterns, influenced by a range of complex climatic systems. For agricultural practices, especially in cotton farming understanding these precipitation dynamics is essential. This review highlights the key regions suitable for cotton cultivation, including the Northern Territory, parts of Queensland, and Western Australia, where tropical climates provide favourable conditions.

This review also examines how climatic drivers, such as the El Niño-Southern Oscillation (ENSO), ENSO Modoki, Ningaloo Niño, the Australian monsoon, the Indian Ocean Dipole (IOD), and the Madden-Julian Oscillation (MJO), interact to shape rainfall variability. These interactions create both challenges and opportunities for cotton producers. Insights from this analysis aim to promote climate literacy within the cotton sector for informed decision-making.

1. INTRODUCTION

Australia is known for having some of the world's most variable rainfall rates (Dey et al., 2021), with Northern Australia being particularly notable for these variations.

It is located in the 'summer dominant' climate class of Australia (Bureau of Meteorology, 2024) and receives about 80% of its annual mean rainfall during November to April. This timeframe corresponds to the wet season (Sharmila & Hendon, 2020) with cooler months comprised during the dry season (Dey et al., 2021). The median annual rainfall in the region ranges from 350mm to >1200mm, depending on the area (Bureau of Meteorology, 2024).

Although rainfall in the area is abundant, Borowiak et al., (2023) assert that since 1950, northwestern Australia has experienced increased mean rainfall, with particularly significant rises during the wet season, in line with Wilks Rogers & Beringer (2017) who found notable increases in rainfall, especially in the Northernmost areas of Northern Australia after analysing 110 years of rainfall data from the region.

Despite this trend, rainfall variability remains a concern, as demonstrated by below-average totals during the 2018–19 and 2019–20 wet seasons, and the intensification of short-duration extreme rainfall events especially in Northern Australia (Bureau of Meteorology & CSIRO, 2020). These fluctuations, both short and long-term, have significant implications for agricultural productivity and business revenues (Sharmila & Hendon, 2020), with agricultural industries in the region particularly vulnerable to these changes (Brown et al., 2019; Klingaman et al., 2013). Cotton production is sensitive to the fluctuations in environmental conditions, and the crop success depends on moisture availability during critical stages such as planting and vegetative growth.

(INTRODUCTION CONT'D)

While Northern Australia's climate generally provides favourable conditions for cotton—with high moisture levels and suitable temperatures—the crop remains susceptible to climate change and weather conditions that can adversely affect yields (Welsh et al., 2022). Currently, over 95% of the cotton area in the Northern Territory is rainfed (Northern Territory Government, n.d.), making cotton a suitable crop for the region if precipitation cycles are well understood.

Precipitation in Australia is shaped by a combination of local interactions between the land, the atmosphere and the ocean; as well as vegetation, and soil moisture (Risbey et al., 2009). In northwestern Australia for example, westerly winds can increase ocean evaporation and enhance rainfall, that along with soil moisture contribute to rainfall patterns (Sharmila & Hendon, 2020).

Additionally, sea surface temperatures (SSTs) around Northern Australia (Evans & Boyer-Souchet, 2012) and tropical cyclones in the Coral Sea can further influence rainfall in northeastern regions (Klingaman et al., 2013).

On a larger scale, seasonal rainfall variability is significantly influenced by the global climatic forces such as El Niño Southern Oscillation (ENSO), which is considered the primary driver of rainfall variability across the country (King et al., 2014), particularly in eastern regions (Risbey et al., 2009). Furthermore, the monsoon brings along precipitation over the North of Australia (Heidemann et al., 2023) that is known to be influenced by other climatic interactions originated in the oceans and the atmosphere.

Thus, this review aims to help understanding the climatic processes that influence precipitation in Northern Australia in order to enhance climate literacy within the cotton industry. It begins by providing an overview of cotton farming areas in the region, followed by an exploration of the key climatic drivers affecting rainfall. Understanding these climatic drivers and their impact on Northern Australia is crucial for improving water use efficiency in dryland and irrigated cotton crops to implement effective strategies that mitigate risks associated with climate variability. At last, this work seeks to support informed decision-making, by offering tools to help anticipating weather events and manage risks in both wet and dry years.

Drivers of Northern Australian climate and weather for cotton production

NORTHERN AUSTRALIA CLIMATE REVIEW 2025

CottonInfo

2. COTTON IN NORTHERN AUSTRALIA

Potential cotton-growing regions in Northern Australia are located within 'Tropical,' Koppen's original scheme, encompassing rainforest (persistently wet), rainforest (monsoonal), and savanna climates (Stern et al., 1999). These climatic conditions are favourable for cotton cultivation, as they provide the warmth and moisture essential for optimal crop development.

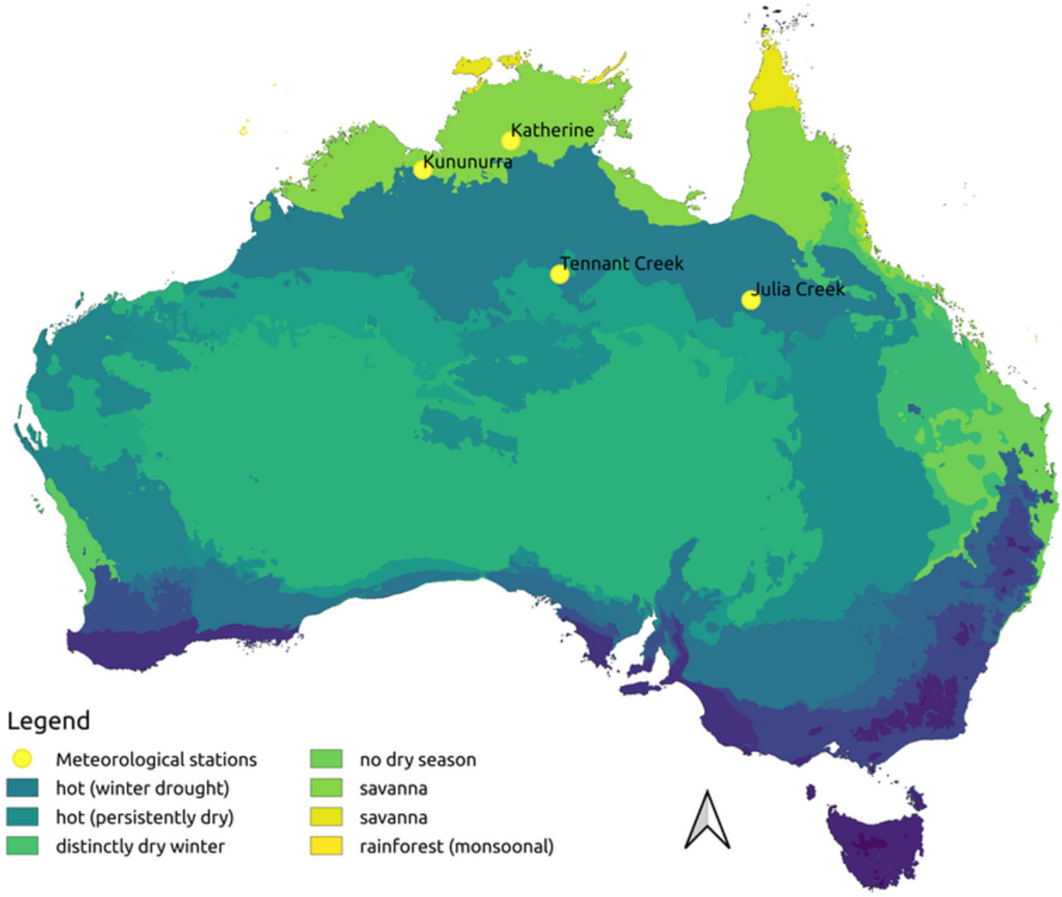


Figure 1 Koppen climate classification in Northern Australia

According to the Northern Territory Government (n.d.), potential regions for dryland cotton cultivation include the West Baines and Roper River Valley, as well as areas in the Northern Barkly. In contrast, irrigated agricultural opportunities have been established in the Katherine region. Also, Cotton Australia (2024) has identified Kununurra (WA), Katherine (NT), and Georgetown (QLD) as promising short-term cotton-growing regions.

Commercial agribusinesses (Bayer, 2023) have also recognised specific valleys within Northern Australia that offer optimal 'planting windows' for cotton cultivation, helping to mitigate pest resistance to particular crop protection strategies.

These valleys include: Ord River/Sandy Desert/Fitzroy River, Douglas/Daly & Katherine, Mareeba/Dimbulah, Gilbert, Flinders, Burdekin, Wiso, Leichhardt River and Normanby River (Figure 2).

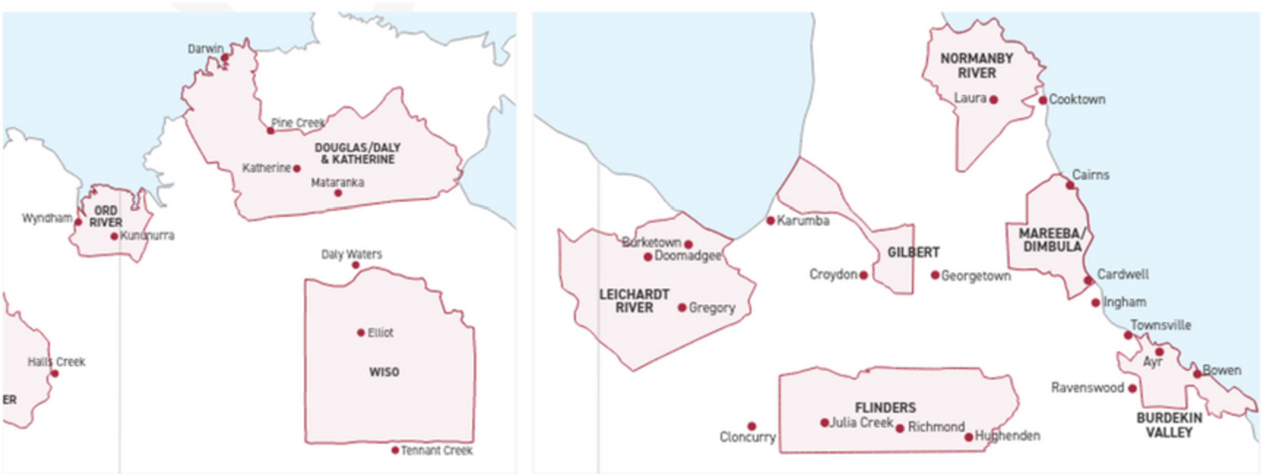


Figure 2 Valleys within Northern Australia (Bayer, 2023)

Taking these regions into consideration, the climatic drivers of precipitation will be discussed in the next sections.

3. CLIMATIC DRIVERS OF PRECIPITATION IN NORTHERN AUSTRALIA

» 3.1. El Niño-Southern Oscillation (ENSO)

ENSO is considered the primary driver of rainfall variability across the country (King et al., 2014). It is a recurring climatic phenomenon that occurs every two to seven years due to fluctuations in Pacific Ocean temperatures and the atmosphere and the eastern and northeastern regions of Australia, particularly during winter, spring, and summer (Klingaman et al., 2013; Risbey et al., 2009).

ENSO has three phases: El Niño (warm phase), La Niña (cool phase), and Neutral (average conditions). The oceanic component of ENSO is monitored through indexes that measure SSTs along the equator (Chen et al., 2019). These indexes are named after the Pacific regions where the temperatures are recorded as El Niño 1+2, El Niño 3, El Niño 3.4 (covering a transition zone between 3 and 4), and El Niño 4.

In contrast, the atmospheric aspect of ENSO is measured by the Southern Oscillation Index (SOI), which tracks the difference in surface air pressure between Tahiti and Darwin, located on opposite sides of the Pacific (Chen et al., 2019).

These ENSO measuring regions, including El Niño Modoki (EMI) are shown in Figure 3.

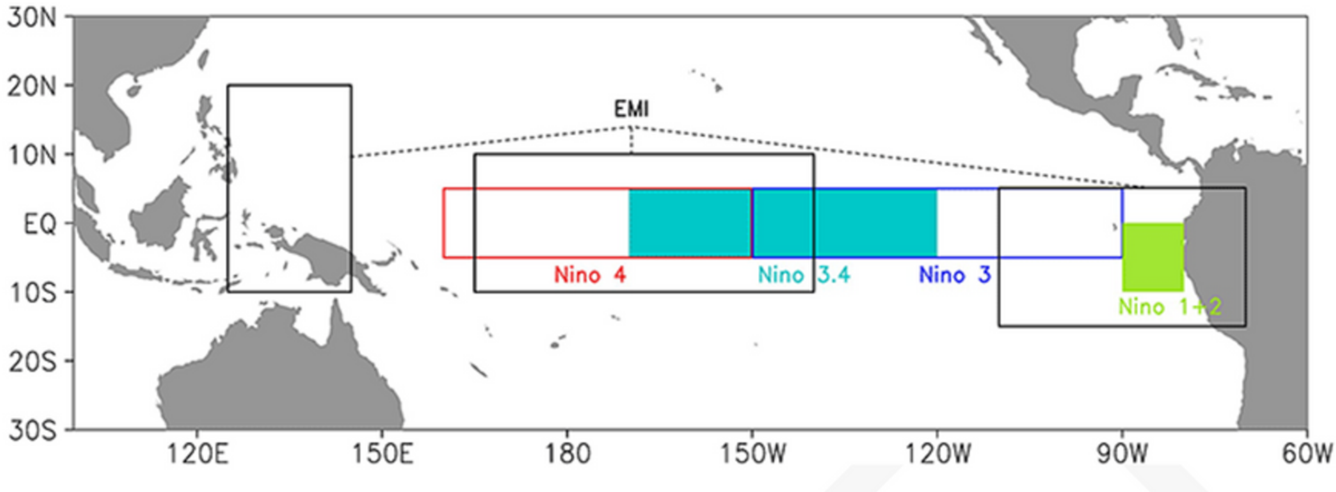


Figure 3 Regions used to calculate indices for climatic drivers of ENSO, ENSO Modoki and IOD (Welsh et al., 2022)

Under neutral ENSO conditions, winds blow from east to west, and SSTs stay within a range of −0.8°C to +0.8°C (Bureau of Meteorology, 2024b). However, during El Niño events, these winds weaken or reverse, causing warm water to accumulate in the central and eastern Pacific. El Niño is typically recognized when SOI values fall below −7 (indicating lower-than-normal pressure in Tahiti and higher-than-normal pressure in Darwin (Bureau of Meteorology, n.d.). Also, El Niño 3.4 SST index exceeds 0.8°C above average (Bureau of Meteorology, 2024b) resulting on reduced rainfall in Australia (Murphy & Ribbe, 2004; Risbey et al., 2009).

In contrast, La Niña is characterised by SOI values rising above +7 (Bureau of Meteorology, n.d.), and El Niño 3.4 SST <−0.8°C below average (Bureau of Meteorology, 2024b). This indicates warm SSTs off the coast of northeastern Australia (King et al., 2014), accompanied by strong east-to-west winds that push warm water toward the western Pacific, resulting in heavy rainfall across Australia (Kajikawa et al., 2010; King et al., 2014; Murphy & Ribbe, 2004; Risbey et al., 2009).

The effects of La Niña on Northern and Eastern Australia are most pronounced during the austral summer (King et al., 2014), although weaker rainfall events may still occur in January (Heidemann et al., 2023). Moreover, strong La Niña events influence the Australian monsoon to arrive about 14 days earlier than the climatological average (29 December), while for weak La Niña events, the onset is close to the climatology (Lisonbee et al., 2020). Although While La Niña's strength has a direct impact on rainfall in Northern and eastern Australia, intense El Niño events do not always lead to drought-like conditions in Australia (Chung & Power, 2017).

» 3.2. ENSO Modoki

Abnormal weather patterns in the Pacific coasts has led to the identification of ENSO Modoki, a global climatic event that significantly impacts temperature and precipitation patterns worldwide. The term Modoki (Japanese, meaning pseudo or quasi) was used by researchers from Japan (Ashok et al., 2007) to describe these events, as their appearances resemble those of El Niño and La Niña ENSO events (Behera & Yamagata, 2018).

ENSO Modoki consists of two phases: El Niño Modoki, characterised by above average SSTs in the central Pacific and cooler SSTs in both the eastern and western tropical Pacific that form a horseshoe-shaped pattern; and La Niña Modoki, where cooler-than-average SSTs appear in the central Pacific while the eastern and western regions show above-average SSTs (Ashok et al., 2007).

The El Niño Modoki Index (EMI) is used for identifying ENSO Modoki events by analysing SSTs across the central, eastern, and western Pacific regions. A strong positive EMI indicates significantly warmer SSTs in the central Pacific compared to the eastern and western Pacific, signaling an ongoing El Niño Modoki event. This is often associated with reduced rainfall in Australia frequently observed in December and March (Taschetto et al., 2010). On the other hand, during the austral summer, particularly in January and February, warming in the central Pacific triggers atmospheric processes that lead to the formation of an anomalous cyclonic circulation off northwestern Australia, strengthening the monsoon circulation resulting in rains.

While El Niño Modoki may not reduce total annual rainfall, it can alter the precipitation cycle in northwestern Australia, resulting in a shorter and more intense monsoon season (Taschetto et al., 2010).

» 3.3. Australian monsoon

The Australian monsoon is a large-scale climatic system driven by annual shifts in solar radiation (Kajikawa et al., 2010). During the monsoon's active phase, winds that typically blow from the east or southeast shift to a nor westerly direction, carrying moist air from surrounding oceans (Bureau of Meteorology, 2024c; Heidemann et al., 2023). This moisture influx leads to increased cloud cover and heavy rainfall (Yim et al., 2014) which play a crucial role in shaping Northern Australia's ecological and agricultural environments.

The behaviour of the Australian monsoon is highly influenced by ENSO, as this global climatic force shifts the location of warm areas in the tropical atmosphere creating convection zones and rainfall (Kumar et al., 1999). In addition, wind-evaporation interactions in the tropical south-eastern Indian Ocean encourage interannual Australian monsoon rain variability over northwestern Australia (Heidemann 2022).

The Australian monsoon can occur at any time from November to April (Bureau of Meteorology, 2024a), and its intensity and timing can vary significantly from year to year (Heidemann 2022). To track and quantify monsoonal patterns Kajikawa et al., (2010) developed the Australian Monsoon Index (AUSMI), which measures average wind speeds at a specific pressure level across parts of Indonesia, the Timor Sea, and Northern Australia. AUSMI is the leading mode of rainfall seasonal variability in northern Australia (Wilks Rogers & Beringer, 2017) and for most of the year is negative, indicating the dominance of easterly trade winds. As the monsoon approaches, these winds weaken, turning AUSMI positive, signaling the arrival of the monsoon (Wilks Rogers & Beringer, 2017).

AUSMI also highlights the relationship between the monsoon and SSTs, with weaker monsoon activity linked to warm SST anomalies in the eastern Pacific, and stronger monsoons associated with cooler SSTs (Kajikawa et al., 2010). Figure 4 displays AUSMI values denoting the presence of the Australian monsoon in red lines.

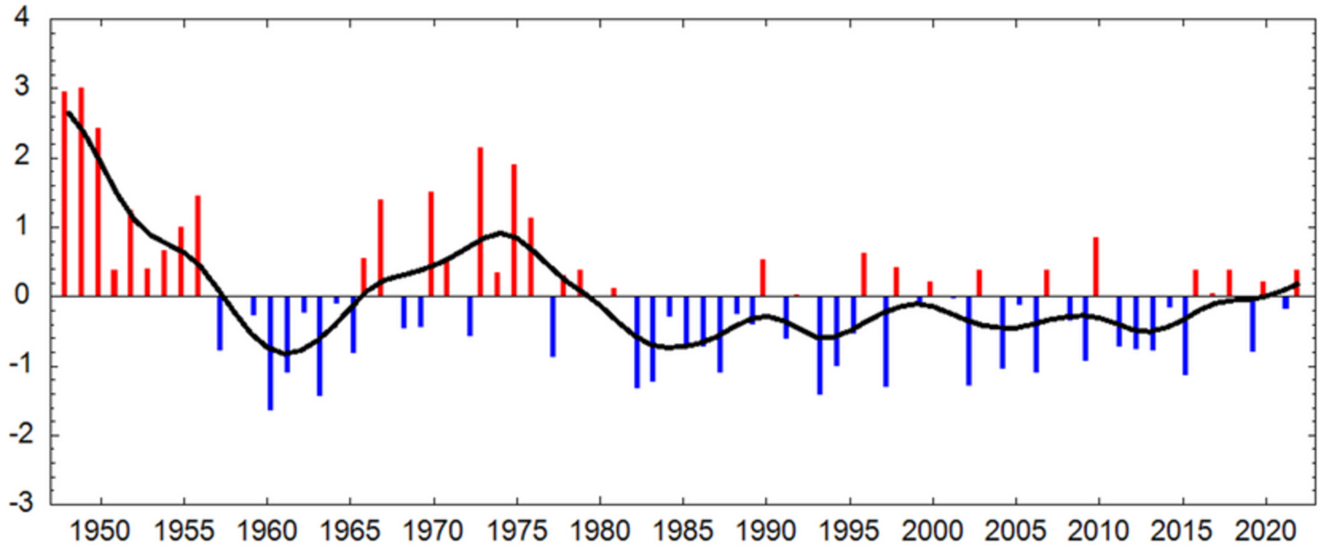


Figure 4 Normalised time series of AUSMI for the period of 1948-2022 (Li, 2024).

» 3.4. Ningaloo Niño

The interaction of Indian Ocean temperatures, ocean currents, and global climatic phenomena influence temperature and rainfall patterns in Western and Northern Australia (Kataoka et al., 2014). A notable phenomenon in this context is the Ningaloo Niño (NNI), characterised by warmer SSTs off the coast of Western Australia, driven by the intensified Leeuwin Current. Ningaloo Niño and Ningaloo Niña are primarily influenced by remote forcings linked to ENSO (Feng et al., 2015) and local ocean-atmosphere interactions (Kataoka et al., 2014; Tozuka et al., 2021).

During Ningaloo Niño events above average SSTs are recorded together with low mean sea level pressure along the western coast of Australia. This has an effect on the atmospheric circulation and rainfall across the Australian continent (Feng et al., 2015),peaks between December and February, and weakens by autumn (Kataoka et al., 2014).

In contrast, Ningaloo Niña events typically result in reduced summer rainfall and even droughts over northwestern Australia due to reduced evaporation from cooler SSTs (Kataoka et al., 2014; Tozuka et al., 2021). Overall, Ningaloo Niño and Ningaloo Niña events significantly impact rainfall, particularly in northwestern Australia, leading to increased or decreased precipitation, respectively (Heidemann et al., 2023). However, Northern Australia may still experience above-average rainfall during Ningaloo Niña events, particularly from a stronger monsoon in January and February (Kataoka et al., 2014).

» 3.5. Indian Ocean Dipole (IOD)

The IOD is a prominent large-scale driver of Australia's climate. A positive IOD event is reflected when low SSTs are low off Sumatra and high in the western Indian Ocean. This temperature anomalies together with wind and precipitation anomalies result in dry conditions in the continent and droughts, particularly in the southeast (Saji et al., 1999; Risbey et al., 2009).

A negative IOD relates to warmer SSTs in the eastern Indian Ocean and results in increased rainfall events in Australia (Ashok et al., 2007). Positive or negative phases can be seen from May to November (Heidemann et al., 2023; Risbey et al., 2009; Saji et al., 1999; Wilks Rogers & Beringer, 2017), peak between August and October and then rapidly decay when the monsoon arrives in the southern hemisphere around the end of spring (Bureau of Meteorology, 2024d).

The Dipole Mode Index (DMI) is the tool to quantify the difference in SSTs between the western (near Africa) and eastern (near Indonesia) parts of the Indian Ocean (Saji et al., 1999) and it is used for the identification and monitoring of IOD. IOD does not have a direct effect on the total rainfall during the Australian monsoon, however, a positive IOD can influence the timing of the monsoon onset delaying the appearance of rains (Ashok et al., 2003). Moreover, a trend has been observed towards more positive IOD events related to the delay in rains; In contrast, a negative IOD has a negligible impact on the Australian monsoon onset timing (Lisonbee et al., 2020).

ENSO and the IOD both influence Australia's climate, but in different ways and regions, however, they are strongly interrelated (Cai et al., 2011). ENSO, which originates in the Pacific, mainly affects rainfall in lower latitudes of eastern Australia, like Queensland. The IOD, which originates in the Indian Ocean, impacts higher latitudes and more western regions of Australia. When these two climate drivers occur simultaneously, their effects on Australian rainfall and temperature become more intense and widespread (Heidemann et al., 2023).

» 3.6. Madden-Julian Oscillation (MJ)

MJO is an atmospheric phenomenon that moves eastward along the equator every 30 to 90 days, influencing tropical rainfall as it passes over the Pacific and Indian Oceans (Risbey et al., 2009; Zhang, 2005) and is a key driver of rainfall variability, particularly during the Australian monsoon season (Wheeler et al., 2009).

The MJO has eight phases, with phases 5 and 6 (active phases) enhancing rainfall in Northern Australia, especially in spring, summer, and autumn. However, its influence shifts to the northeast during winter due to interactions with trade winds (Wheeler et al., 2009; Borowiak et al., 2023).

The MJO and ENSO do not act independently; their combined states are critical for predicting rainfall variability. The inactive phases of MJO can accentuate the dry effects of El Niño, while can weaken La Niña effects (Risbey et al., 2009). On the other hand, through the pass of the MJO active phases, the likelihood of extreme weekly rainfall events increases (Wheeler & Hendon, 2004).

» 3.7. Summary

Table 1 Summary table of key drivers of Northern Australian climate and weather

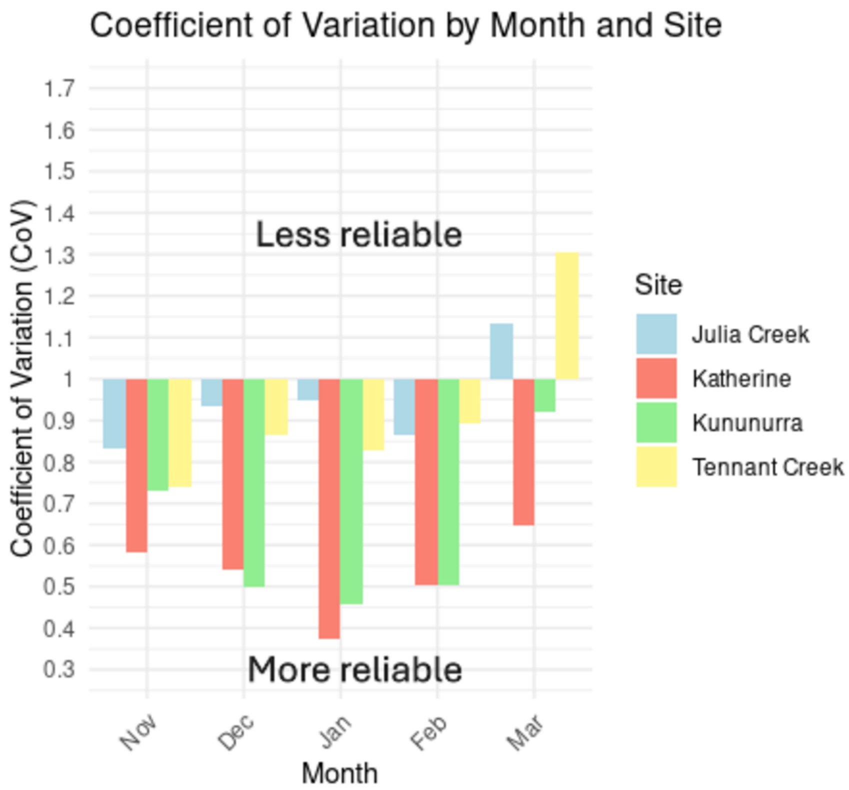
Driver	Index Range	Key influences
El Niño–Southern Oscillation (ENSO)	• Niño 3.4 SST Index – El Niño event: >0.8 – La Niña event:<-0.8. • SOI (Southern Oscillation Index): – El Niño event: < -7 – La Niña event: >7	El Niño events are associated with reduced rainfall and droughts. La Niña events bring increased rainfall to Northern Australia particularly during the austral summer. It may cause an earlier monsoon onset.
El Niño Modoki	Modoki Index (EMI) – El Nino Modoki: positive EMI – La Nina Modoki: negative EMI	El Nino Modoki brings drier conditions to Australia. It may cause a shorter and more intense monsoon season.
Australian Monsoon	Australian Monsoon Index (AUSMI) – AUSMI is negative for most of the year. – AUSMI is positive when these winds weaken denoting the transition into the monsoon phase.	Increased cloud cover and rainfall in Northern Australia. Weaker monsoon activity linked to warm SSTs anomalies in the eastern Pacific; stronger monsoon linked to cooler SSTs
Ningaloo Niño	Ningaloo Niño Index (NNI). - Warm SST anomalies along WA coast – Ningaloo Niño event: warmer SSTs than normal off the coast of Western Australia (intensified Leeuwin Current). – Ningaloo Niña event: cooler SSTs than normal off the coast of Western Australia.	Positive Ningaloo Niño events can increase rainfall in Northern Australia particularly during December to February. Ningaloo Nina results in reduced summer rainfall and droughts over Northwestern Australia, however Northern Australia may still experience high rainfall particularly due to strong monsoons
Indian Ocean Dipole (IOD)	Dipole Mode Index (DMI) – Positive IOD event: Positive DMI- cooler SSTs over the Indian Ocean. – Negative IOD event: Negative DMI -warmer SSTs over the Indian Ocean.	A positive IOD event can delay Australian monsoon onset (delay in rains) causing drier than normal conditions. Negative IOD does not affect monsoon onset.
Madden-Julian Oscillation (MJO)	Phase index 1-8 (divided by phases indicating location along the equator)	- Phases 5 to 6: Enhanced rainfall in Northern Australia - Phases 6-7: Decreased rainfall as MJO moves further east

4. RAINFALL REALIABILITY IN NORTHERN AUSTRALIA

The Coefficient of Variation (CoV) is a useful indicator for assessing rainfall patterns compared to monthly averages. It indicates the reliability of daily rainfall relative to expected totals. Lower CoV values suggest a more consistent rainfall pattern, making these months more dependable for planning in agriculture.

This value expressed as a decimal where the general statistical rule >1 is considered high variance and a value <1 is considered low variance (Figure 5).

Figure 5 Coefficient of Variation for November, December, January, February and March for Julia Creek, Katherine, Kununurra and Tennant Creek from rainfall data recorded from 1994.



5. CONCLUSIONS

Rainfall variability in Northern Australia is significantly influenced by complex interactions between global and regional climatic factors, which has important implications for cotton production in Northern Australia. Regions like Katherine in the Northern Territory, Kununurra in Western Australia, and Georgetown in Queensland represent prime locations for cotton farming, benefiting from suitable climatic conditions that support crop growth but remain vulnerable to rainfall variability.

The Australian monsoon brings heavy rainfall to Northern Australia during the wet season typically from November to April. El Niño years might reduce rainfall in Northern Australia, as well as a positive IOD and a El Niño Modoki can lead to drier conditions.

(CONCLUSIONS CONT'D)

On the other hand, La Niña, La Niña Modoki, and a negative IOD increase precipitation rates in the region with La Niña years often bringing an early onset and increased monsoon activity.

A key intraseasonal driver of rainfall variability is MJO, which triggers heavy rainfall and affects the timing of monsoon onset and active periods. All of these climatic drivers play an important role in rainfall dynamics, therefore impacting cotton farming decisions and yield outcomes.

By understanding these climatic influences, growers can better anticipate rain episodes and prepare for variable climatic patterns. For this, the climate driver update (Bureau of Meteorology, 2024) provides accessible up to date information on climatic indices and comparisons with average values to identify the presence of climatic events. Also, IOD (Bureau of Meteorology, 2024) and MJO (Bureau of Meteorology, 2024e) information is available online (Bureau of Meteorology, 2024).

Also, real time monsoonal activity can be tracked through the NOAA website (NOAA, 2024) and the BoM's monsoon onset tool is useful also from June to October each year (Bureau of Meteorology, 2024f)

6. REFERENCES

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), 2006JC003798. https://doi.org/10.1029/2006JC003798

Ashok, K., Guan, Z., & Yamagata, T. (2003). Influence of the Indian Ocean Dipole on the Australian winter rainfall. Geophysical Research Letters, 30(15). https://doi.org/10.1029/2003GL017926

Bayer. (2023). Growing Cotton in Northern Australia 2023/24 Grower Guide.

Borowiak, A., King, A., & Lane, T. (2023). The Link Between the Madden-Julian Oscillation and Rainfall Trends in Northwest Australia. Geophysical Research Letters, 50(8), e2022GL101799. https://doi.org/10.1029/2022GL101799

Brown, J. N., Ash, A., MacLeod, N., & McIntosh, P. (2019). Diagnosing the weather and climate features that influence pasture growth in Northern Australia. Climate Risk Management, 24, 1–12. https://doi.org/10.1016/j.crm.2019.01.003

Bureau of Meteorology. (2024a). Climate Classification Maps http://www.bom.gov.au/climate/maps/averages/climate-classification/?maptype=seasb

Bureau of Meteorology. (2024b). Climate Driver Update. http://www.bom.gov.au/climate/enso/

Bureau of Meteorology. (2024c). The Australian Monsoon http://www.bom.gov.au/climate/about/australian-climate-influences.shtml?bookmark=monsoon

Bureau of Meteorology. (2024d). Indian Ocean Influences on Australian Climate http://www.bom.gov.au/climate/iod/

Bureau of Meteorology. (2024e). Tropical Monitoring and Outlooks http://www.bom.gov.au/climate/mjo/

Bureau of Meteorology. (2024f). Northern Rainfall Onset for the 2024 to 2025 season http://www.bom.gov.au/climate/rainfall-onset/

Bureau of Meteorology. (n.d.). Southern Oscillation Index. http://www.bom.gov.au/climate/enso/soi/about-soi.html

Bureau of Meteorology & CSIRO. (2020). State of The Climate 2020 (Nos. 978-1-4863-1509–3).

Cai, W., Rensch, P. van, Cowan, T., & Hendon, H. H. (2011). Teleconnection Pathways of ENSO and the IOD and the Mechanisms for Impacts on Australian Rainfall. Journal of Climate, 24(15), 3910–3923. https://doi.org/10.1175/2011JCLI4129.1

Chen, N., Thual, S., & Hu, S. (2019). El Niño and the Southern Oscillation: Observation . In Reference Module in Earth Systems and Environmental Sciences. Elsevier. https://doi.org/10.1016/B978-0-12-409548-9.11766-X

Chung, C. T. Y., & Power, S. B. (2017). The non-linear impact of El Nino, La Nina and the Southern Oscillation on seasonal and regional Australian precipitation. Journal of Southern Hemisphere Earth Systems Science, 67(1), 25–45. https://doi.org/10.1071/es17004

(6. REFERENCES CONT'D)

Cotton Australia. (2024). Where is cotton grown? https://cottonaustralia.com.au/where-is-cotton-grown

Dey, R., Bador, M., Alexander, L. V., & Lewis, S. C. (2021). The drivers of extreme rainfall event timing in Australia. International Journal of Climatology, 41(15), 6654–6673. https://doi.org/10.1002/joc.7218

Evans, J. P., & Boyer-Souchet, I. (2012). Local sea surface temperatures add to extreme precipitation in northeast Australia during La Niña. Geophysical Research Letters, 39(10). https://doi.org/10.1029/2012GL052014

Feng, M., Hendon, H. H., Xie, S.-P., Marshall, A. G., Schiller, A., Kosaka, Y., Caputi, N., & Pearce, A. (2015). Decadal increase in Ningaloo Niño since the late 1990s. Geophysical Research Letters, 42(1), 104–112. https://doi.org/10.1002/2014GL062509

Feng, M., McPhaden, M. J., Xie, S.-P., & Hafner, J. (2013). La Niña forces unprecedented Leeuwin Current warming in 2011. Scientific Reports, 3(1), 1277. https://doi.org/10.1038/srep01277

Ghelani, R. P. S., Oliver, E. C. J., Holbrook, N. J., Wheeler, M. C., & Klotzbach, P. J. (2017). Joint Modulation of Intraseasonal Rainfall in Tropical Australia by the Madden-Julian Oscillation and El Niño-Southern Oscillation. Geophysical Research Letters, 44(20), 10,754-10,761. https://doi.org/10.1002/2017GL075452

Heidemann, H., Cowan, T., Henley, B. J., Ribbe, J., Freund, M., & Power, S. (2023). Variability and long-term change in Australian monsoon rainfall: A review. WIREs Climate Change, 14(3), e823. https://doi.org/10.1002/wcc.823

Kajikawa, Y., Wang, B., & Yang, J. (2010). A multi-time scale Australian monsoon index. International Journal of Climatology, 30(8), 1114–1120. https://doi.org/10.1002/joc.1955

Kataoka, T., Tozuka, T., Behera, S., & Yamagata, T. (2014). On the Ningaloo Niño/Niña. Climate Dynamics, 43(5), 1463–1482. https://doi.org/10.1007/s00382-013-1961-z

King, A. D., Klingaman, N. P., Alexander, L. V., Donat, M. G., Jourdain, N. C., & Maher, P. (2014). Extreme Rainfall Variability in Australia: Patterns, Drivers, and Predictability. Journal of Climate, 27(15), 6035–6050. https://doi.org/10.1175/JCLI-D-13-00715.1

Klingaman, N. P., Woolnough, S. J., & Syktus, J. (2013). On the drivers of inter-annual and decadal rainfall variability in Queensland, Australia. International Journal of Climatology, 33(10), 2413–2430. https://doi.org/10.1002/joc.3593

Lisonbee, J., Joel Lisonbee, Lisonbee, J., Joachim Ribbe, Ribbe, J., Matthew C. Wheeler, & Wheeler, M. C. (2020). Defining the north Australian monsoon onset: A systematic review: 44(3), 398–418. https://doi.org/10.1177/0309133319881107

Li, J (2024). Australian Monsoon Index (AUSMI) 1943-2023. Professor Jianping Li's Homepage. http://lijianping.cn/dct/page/65582

Lo, F., Wheeler, M. C., Meinke, H., & Donald, A. (2007). Probabilistic Forecasts of the Onset of the North Australian Wet Season. Monthly Weather Review, 135(10), 3506–3520. https://doi.org/10.1175/MWR3473.1

Murphy, B. F., & Ribbe, J. (2004). Variability of southeastern Queensland rainfall and climate indices. International Journal of Climatology, 24(6), 703–721. https://doi.org/10.1002/joc.1018

National Weather Service. Climate Prediction Center NOAA (2024). Real Time Monsoon Index. https://www.cpc.ncep.noaa.gov/products/Global_Monsoons/Asian_Monsoons/monsoon_index.shtml

Northern Territory Government. (n.d.). Cotton in the Northern Territory—Facts and stats. https://industry.nt.gov.au/__data/assets/pdf_file/0005/1062518/cotton-facts-and-stats.pdf

Risbey, J. S., Pook, M. J., McIntosh, P. C., Wheeler, M. C., & Hendon, H. H. (2009). On the Remote Drivers of Rainfall Variability in Australia. Monthly Weather Review, 137(10), 3233–3253. https://doi.org/10.1175/2009MWR2861.1

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. https://doi.org/10.1038/43854

Sekizawa, S., Hisashi Nakamura, Nakamura, H., Yu Kosaka, & Kosaka, Y. (2021). Remote influence of the interannual variability of the Australian summer monsoon on wintertime climate in East Asia and the western North Pacific. Journal of Climate, 1, 1–54. https://doi.org/10.1175/jcli-d-21-0202.1

Sharmila, S., & Hendon, H. H. (2020). Mechanisms of multiyear variations of Northern Australia wet-season rainfall. Scientific Reports, 10(1), 5086. https://doi.org/10.1038/s41598-020-61482-5

Stern, H., de Hoedt, G., & Ernst, J. (1961). Objective classification of Australian climates.

Taschetto, A. S., Haarsma, R. J., Gupta, A. S., Ummenhofer, C. C., & England, M. H. (2010). Teleconnections associated with the intensification of the Australian monsoon during El Niño Modoki events. IOP Conference Series: Earth and Environmental Science, 11(1), 012031. https://doi.org/10.1088/1755-1315/11/1/012031

Taschetto, A. S., Ummenhofer, C. C., Sen Gupta, A., & England, M. H. (2009). Effect of anomalous warming in the central Pacific on the Australian monsoon. Geophysical Research Letters, 36(12). https://doi.org/10.1029/2009GL038416

Drivers of Northern Australian climate and weather for cotton production

NORTHERN AUSTRALIA CLIMATE REVIEW 2025

CottonInfo

(6. REFERENCES CONT'D)

Tozuka, T., Feng, M., Han, W., Kido, S., & Zhang, L. (2021). 8 - The Ningaloo Niño/Niña: Mechanisms, relation with other climate modes and impacts. In S. K. Behera (Ed.), Tropical and Extratropical Air-Sea Interactions (pp. 207–219). Elsevier. https://doi.org/10.1016/B978-0-12-818156-0.00006-X

Welsh, J. M., Taschetto, A. S., & Quinn, J. P. (2022). Climate and agricultural risk: Assessing the impacts of major climate drivers on Australian cotton production. European Journal of Agronomy, 140, 126604. https://doi.org/10.1016/j.eja.2022.126604

Wheeler, M. C., & Hendon, H. H. (2004). An All-Season Real-Time Multivariate MJO Index: Development of an Index for Monitoring and Prediction. Monthly Weather Review, 132(8), 1917–1932. https://doi.org/10.1175/1520-0493(2004)132<1917:AARMMI>2.0.CO;2

Wheeler, M. C., Hendon, H. H., Cleland, S., Meinke, H., & Donald, A. (2009). Impacts of the Madden–Julian Oscillation on Australian Rainfall and Circulation. Journal of Climate, 22(6), 1482–1498. https://doi.org/10.1175/2008JCLI2595.1

Wilks Rogers, C. D., & Beringer, J. (2017). Describing rainfall in Northern Australia using multiple climate indices. Biogeosciences, 14(3), 597–615. https://doi.org/10.5194/bg-14-597-2017

Yim, S.-Y., Wang, B., Liu, J., & Wu, Z. (2014). A comparison of regional monsoon variability using monsoon indices. Climate Dynamics, 43(5), 1423–1437. https://doi.org/10.1007/s00382-013-1956-9

Zhang, C. (2005). Madden-Julian Oscillation. Reviews of Geophysics, 43(2). https://doi.org/10.1029/2004RG000158

CottonInfo HELPING YOU GROW

AgEcon RESEARCH, DEVELOPMENT & EXTENSION SERVICES

For further information:

Visit www.cottoninfo.com.au

Contact CottonInfo Energy & Climate Technical Lead Jon Welsh via 0458 215 335 or jon@agecon.com.au