WORLD
METEOROLOGICAL
ORGANIZATION

Understanding ENSO Indices in a Warming Climate

ONI vs. RONI indices

Non-Technical Briefing Note | April 2026

Why This Matters

El Niño and La Niña events are two opposite facets of a naturally occurring climate pattern known as the El Niño–Southern Oscillation (ENSO), which are among the most powerful and far-reaching climate phenomena on Earth. They reshape rainfall patterns, fuel droughts and floods, disrupt food systems, and influence the frequency of extreme weather events across every inhabited continent. Many entities, including governments, humanitarian organizations, water managers, and farmers all rely on accurate, timely ENSO monitoring and forecasting to plan and respond effectively.

These decisions are anchored by Sea Surface Temperature (SST) indices – numerical measures that track the state of the tropical Pacific Ocean. But as the climate warms, the traditional way of computing these indices is introducing systematic biases that distort the picture. Understanding the difference between the conventional Oceanic Niño Index (ONI) and its improved counterpart, the Relative Oceanic Niño Index (RONI), is therefore not merely an academic exercise: it has direct implications for the quality and timeliness of early warnings, and ultimately for lives and livelihoods.

Background: ENSO and how it is measured

El Niño–Southern Oscillation (ENSO) is the dominant source of year-to-year climate variability on the planet. It arises from the coupled interaction between the tropical Pacific Ocean and the overlying atmosphere, oscillating between two opposing states. During an El Niño, anomalously warm sea surface temperatures (SSTs) develop across the central and eastern equatorial Pacific, weakening the trade winds, shifting the centre of tropical rainfall eastward toward the central and/or eastern equatorial Pacific, and triggering a cascade of atmospheric teleconnections that affect weather patterns from the southern United States to southern Africa. La Niña represents the mirror image: anomalously cold SSTs in the same region, strengthened trade winds, and rainfall shifting westward, intensifying across the Maritime Continent, and suppressed rainfall over the central equatorial Pacific.

ENSO operates on timescales of two to seven years, peaking typically in the boreal winter (November–February). The strength of an event can matter for the likelihood of events: a weak or moderate El Niño might slightly increase the chances of rains to drought-prone East Africa, but a strong one can make it even likelier. The difference between a "weak" and "strong" El Niño is not merely semantic. It governs whether governments activate emergency protocols, whether humanitarian pre-positioning occurs, and whether farmers plant drought-resistant or water-intensive crops.

Since the 1980s, the primary tool for tracking ENSO from an oceanic perspective has been a family of SST anomalies indices defined over specific boxes in the equatorial Pacific. The most widely used of these is the Niño-3.4 index, which averages SST anomalies over the region spanning [120°W–170°W; 5°S–5°N] - a zone that sits in the east-central equatorial Pacific Ocean and is highly sensitive to ENSO-driven changes. The Oceanic Niño Index (ONI) is the three-month running mean of the Niño-3.4 index, computed as a departure from a 30-year climatological average. NOAA's Climate Prediction Center (CPC) uses the ONI as a core component of its ENSO alert system, applying thresholds of ±0.5°C to declare El Niño or La Niña conditions.

The Australian Bureau of Meteorology (BOM) uses an alternate SST dataset to calculate the Niño-3.4 index, using weekly and monthly values to assess the state of ENSO, and a threshold of ±0.8°C for defining El Niño or La Niña events. For simplicity, this document will refer to the ONI and RONI as examples of SST-based indices.

SST-based indices like the ONI are typically preferred over atmospheric indicators such as the Southern Oscillation Index (SOI), winds, or rainfall anomalies because they are less noisy on short timescales, making them better suited for real-time monitoring. They also serve as anchor points for seasonal forecast model output, public communication, and the humanitarian trigger systems that initiate preparedness actions. Their reliability is therefore of paramount importance.

The Problem: How Global Warming corrupts the ONI

The ONI is founded on an assumption: sea surface temperature (SST) anomalies in the Niño-3.4 region, measured relative to a historical baseline, adequately represent the state of ENSO. This assumption implicitly requires a stationary climate, where the statistical properties of the background state remain stable over time.

That assumption is no longer valid.

Anthropogenic warming has introduced a persistent, externally forced increase in tropical ocean temperatures. This trend is independent of ENSO dynamics, yet it is embedded directly within ONI calculations. As a result, the ONI no longer isolates interannual variability; it systematically conflates natural oscillations with long-term climate change. Changes in the equatorial Pacific SST anomalies are also increasingly misaligned from the changes in the overlying atmospheric circulation. Because ENSO is a coupled ocean-atmosphere phenomenon, changes in the ocean must be accompanied by changes in the atmosphere.

This introduces a structural, time-evolving bias with compounding consequences:

- **Systematic inflation of El Niño intensity:** Positive SST anomalies are amplified by the underlying warming trend, leading to overestimation of event strength. Apparent “record” events may reflect baseline drift as much as physical variability. The 2015/16 El Niño, for example, appeared in the ONI as the strongest on record — but when the background warming of ~0.3–0.5°C since 1982 is accounted for, it was comparable in strength to the 1997/98 and 1982/83 events. The 2023/24 El Niño was considered one of the top five strongest El Niños in the traditional data, but it is ranked number ten in the relative data.
- **Systematic attenuation of La Niña signals:** Negative anomalies are dampened by elevated background temperatures, increasing the likelihood of under-detection or misclassification of La Niña events despite consistent atmospheric and impact-based evidence. The 2016/17 La Niña barely cleared NOAA's ±0.5°C threshold and did not meet BOM's ±0.8°C criterion — despite atmospheric indicators and regional impacts consistent with a moderate event.
- **Bias in real-time monitoring:** The use of lagged climatologies (e.g., centred 30-year means updated every five years) introduces a mismatch between the reference state and current ocean conditions, particularly in a rapidly warming system. This artificially enhances positive anomalies in recent periods. This means that for the most recent 15 years, the ONI values in use are computed against a climatology that may be significantly cooler than the contemporary ocean state, exaggerating positive anomalies.

A Concrete Humanitarian Consequence

The 2016/17 La Niña provides a striking illustration of the operational stakes. Following the 2015/16 El Niño, genuinely cold SST anomalies developed in the central Pacific, consistent with a moderate La Niña. Yet elevated background ocean temperatures meant the Oceanic Niño Index (ONI) barely crossed the ±0.5°C threshold. This produced a split signal: NOAA declared La Niña, while Bureau of Meteorology initially did not. That inconsistency fed into early warning systems for East Africa, where ENSO plays a critical role. By the time impacts intensified, the window for prevention had narrowed. By June 2017, 26.5 million people in the Horn of Africa were affected—through crop losses, livestock deaths, and worsening food insecurity.

A clearer signal such as that provided by RONI could have supported earlier, more decisive action. In this context, precision is not academic; it directly shapes the timeliness of response. While other factors, including a strong negative Indian Ocean Dipole (IOD), also contributed to the impacts in the Horn of Africa and Australia, the ambiguity in ENSO diagnostics remains a critical limitation for early warning systems.

What is the difference between ONI and RONI?

The Oceanic Niño Index (ONI)

The ONI is computed as the three-month running mean of SST anomalies in the Niño-3.4 region, expressed as a departure from a 30-year monthly climatological mean. NOAA currently uses a base period that is centered in the historical record and lagged in the recent record (most recently 1996–2025 is used for the real-time period). BOM's SST index dataset uses the 1991–2020 period. An El Niño (La Niña) is declared when the ONI exceeds +0.5°C (−0.5°C) for at least five consecutive overlapping seasons at NOAA; BOM uses a higher threshold of ±0.8°C, reflecting an alternative declaration standard, with at least three consecutive months exceeding the threshold as the oceanic component used to define an event.

The ONI has clear practical advantages: it is simple to compute and deeply embedded in operational communication systems, alert thresholds, and statistical forecasting frameworks. However, its fundamental limitation lies in its reliance on a lagging climatological baseline. As global ocean temperatures rise, this approach increasingly fails to represent the contemporary climate state, weakening the clarity and consistency of ENSO signals.

The Relative Oceanic Niño Index (RONI)

The RONI, first proposed by van Oldenborgh et al. (2021) and further developed by L'Heureux et al. (2024), addresses the ONI's limitations with a conceptually elegant adjustment. Rather than measuring the Niño-3.4 region against a fixed historical average, the RONI measures it against the rest of the tropics in real time. The formula is:

RONI = (Niño-3.4 anomaly − Tropical mean anomaly [20°S–20°N]) × Scaling factor

The tropical mean anomaly (the average SST anomaly across 20°S–20°N) captures the broad background signal of warming, both its slowly rising trend and any variability shared across the entire tropical belt. By subtracting this from the Niño-3.4 anomaly, the RONI isolates the temperature contrast between the east-central Pacific region and the rest of the tropics, as well as the signal most directly relevant to dynamical linkages to the tropical atmosphere, such as convection and rainfall.

A scaling factor is applied to ensure that the RONI has the same variance as the ONI, so that existing declaration thresholds (e.g. ±0.5°C, ±0.8°C) can be applied directly without modification. This is an important operational feature: it means the RONI is similar enough to the ONI that it can be adopted without requiring agencies to recalibrate their entire monitoring and communication infrastructure.

In simple terms

The ONI asks: "How warm is the central Pacific compared to its historical average?" The RONI asks: "How warm is the central Pacific compared to the rest of the tropics right now?" In a warming world, only the second question reliably distinguishes an ENSO event from longer-term background changes.

Scientific rationale and added value of RONI

Physical justification

The RONI is not a statistical correction; it has a strong physical basis rooted in how the tropical atmosphere responds to ocean temperature patterns. Near the equator, the Coriolis effect is weak, which means that horizontal temperature gradients in the free troposphere are small. As a result, the temperature of the tropical upper troposphere is controlled by the average surface conditions across the entire tropical belt, not by the temperature at any single location.

What determines where deep convection (and therefore rainfall) occurs is the local SST relative to the tropical mean state. If the Niño-3.4 region is warmer than average relative to the rest of the tropics, the overlying air column becomes less stable, promoting rising motion, cloud development, and rainfall. If it is cooler than average relative to the rest of the tropics, the atmosphere is more stable and suppresses convection. This is the physical mechanism behind ENSO's global rainfall teleconnections, and it operates on relative SST, not absolute SST.

This reasoning explains why the RONI more closely tracks the changes in tropical atmospheric circulation including the Walker Circulation; that are the hallmark of ENSO. It also explains why absolute SST warming that is uniform across the tropics does not, by itself, produce ENSO-like impacts: it is the gradient across the tropical Pacific that matters, not the overall level of warming.

Consistency in historical event identification

The non-stationarity in the climate means there can be dramatic shifts in the historical classification of El Niño and La Niña events. When a different 30-year climatology is subtracted from the absolute SSTs, the timing and strength of past El Niño and La Niña can change. L'Heureux et al. (2024) confirmed this across three independent SST datasets (ERSSTv5, HadISST, COBE-SST) and showed that the RONI produces a more consistent classification of historical El Niño and La Niña events regardless of which 30-year baseline is used; a property the ONI conspicuously lacks.

Improved teleconnections

A key test of any ENSO index is how well it predicts the downstream impacts that users care about: rainfall, temperature, and extreme events in ENSO-sensitive regions. When ENSO teleconnection patterns are computed using the RONI rather than the ONI, several improvements emerge:

- Precipitation anomaly patterns over the Maritime Continent, central Pacific, Australia, and the Americas are sharper and more symmetric, reflecting the classic ENSO dipole.
- In the upper-level atmospheric circulation (200 hPa geopotential height), the RONI produces a more balanced pattern of positive and negative anomalies globally, reducing the widespread positive height bias when ONI is used.
- Over eastern Australia during June–August and the southern United States during January–March, the RONI explains approximately 5–10 percentage points more of the interannual precipitation variance than the ONI over the entire historical record.
- During the August-October season, RONI has a stronger relationship with Atlantic tropical cyclone metrics than the ONI (e.g. accumulated cyclone energy, number of tropical storms and hurricanes).
- The year-to-year variability of the Indian Summer Monsoon Rainfall (June-September) and its large-scale circulation patterns are more strongly tied to RONI.
- The difference in precipitation teleconnections between the RONI and ONI closely matches the global warming signal in rainfall, confirming that the improvement comes specifically from removing the climate change component.

Defining ENSO indices in a warming climate

The challenge of defining ENSO in a warming world goes beyond choosing between two indices. It raises a more fundamental question: what exactly should an ENSO index measure, and how should it be computed when the climate system itself is changing?

Conventionally, ENSO monitoring agencies follow World Meteorological Organization (WMO) guidance and compute SST anomalies against a single fixed 30-year baseline, updated every decade. The assumption is that a 30-year period is long enough to average out interannual variability including ENSO itself, while providing a stable reference. In a stationary climate, this works. In a warming climate, it creates three interconnected problems.

Problem 1: The baseline shifts with warming

Each successive 30-year climatology is warmer than the previous one. When a new baseline replaces an older one, the anomalies for any given period change retrospectively events that were El Niño under one baseline may become neutral under another. This creates an unstable historical record and periodic discontinuities in monitoring products. NOAA's decision to update its baseline every five years partially addresses this but introduces its own discontinuities and still cannot keep pace with the warming trend.

BOM's current operational system has recently transitioned to a 1991–2020 climatology, but does not update the base-period on a regular cycle. While less frequent updates to the base period reduce changes to the event record over time, they also allow the climatology to become increasingly influenced by global warming which can negatively affect real time assessments.

Problem 2: The threshold becomes a biased trigger

If the background warming trend is not removed, the declaration threshold (e.g., ±0.5°C or ±0.8°C) becomes progressively easier to reach for El Niño events and harder to reach for La Niña events. At current warming rates, the tropical average SST is rising at approximately +0.11°C per decade. Over 30 years, this is sufficient to shift the effective El Niño threshold by about 0.3°C; a substantial fraction of the declaration criterion.

In a hypothetical future where warming continues and no adjustment is made; there could be a scenario in which near-permanent El Niño conditions are declared simply because the background ocean has warmed past the threshold, even in the absence of any genuine ENSO forcing. While this is an extreme example, it illustrates the direction of bias and the urgency of addressing it now, before the gap between the climatology and the current climate state becomes unmanageable.

Problem 3: El Niño and La Niña are a physical oscillation, not an absolute state

ENSO is fundamentally a coupled oscillation: the ocean and atmosphere reinforce each other in both the warm and cold phases, producing impacts that are largely symmetric. A monitoring system that systematically favours positive anomalies (El Niño) over negative ones (La Niña) therefore misrepresents the physical phenomenon it is supposed to track.

The RONI mitigates all three problems by design. By expressing Niño-3.4 anomalies relative to the contemporaneous tropical mean SST anomaly, it reduces sensitivity to the choice of climatological baseline and effectively removes the influence of background warming. As a result, RONI provides a more balanced representation of ENSO variability.

> **Key principle**
>
> RONI defines ENSO relative to the contemporary state of the climate; not against an arbitrary historical baseline that grows increasingly obsolete as the planet warms. This aligns the index with the physics of ENSO: a coupled ocean-atmosphere phenomenon that is more sensitive to anomalous temperature gradients, not by absolute temperature levels.

ONI vs. RONI: Summary Comparison

Feature	ONI (Traditional)	RONI (Relative)
Basis	SST anomaly in Niño-3.4 vs. a fixed 30-year historical average	Niño-3.4 anomaly minus the contemporaneous tropical-mean SST anomaly (20°S–20°N), rescaled to preserve variance
Climate change sensitivity	High — background warming inflates El Niño and suppresses La Niña readings over time	Low — tropical mean warming is subtracted reducing sensitivity. However, trend is not canceled-

WORLD METEOROLOGICAL ORGANIZATION

Feature	ONI (Traditional)	RONI (Relative)
Historical consistency	Event classifications shift when the baseline period changes; historical records are periodically revised	More stable across different baseline periods; historical record is more robust
Physical basis	Measures absolute ocean warmth against a historical mean — increasingly displaced from coupling with atmosphere as the baseline ages	Measures warmth relative to the rest of the tropics — directly linked to local atmospheric instability, convection onset/decay, and Walker circulation changes
Forecast skill	Linearly detrending the index increases skill, meaning that the warming signal is not well predicted	Comparable to ONI for most of the year; marginally lower in spring once the tropical mean is removed
Teleconnections & impacts	Global rainfall and circulation teleconnections are partially confused with the warming trend	Cleaner ENSO signal; explains ~5–10% more precipitation variability in key impact regions (e.g. eastern Australia, southern United States)
Operational readiness	Widely established; existing thresholds and communication products are built around it	Uses the same thresholds as ONI after rescaling; open-source code available

Implications for ENSO monitoring and forecasting

The case for the RONI rests not only on its scientific merits but on its practical value across the full chain of ENSO services — from real-time monitoring through to seasonal forecasting, impact assessment, and communication. The following sections examine each dimension.

Real-time monitoring

One of the practical advantages of the RONI is that it can be computed in real time without any additional data sources.

The removal of the tropical mean anomaly in RONI improves real-time monitoring by comparing the Niño-3.4 index against more recent changes contained within the tropical mean. The instability of the ONI's historical record — where events are periodically reclassified — is a recognised operational inconvenience that the RONI reduces.

ENSO declaration and alert systems

The RONI's compatibility with existing declaration thresholds — achieved through the variance-preserving scaling factor — is a critical feature for operational transition. BOM's ±0.8°C threshold and NOAA's ±0.5°C threshold can both be applied to the RONI without modification, enabling a comparatively smooth changeover in alert systems.

Analysis of the period since 2015, during which the BOM ENSO Alert System has been operational, shows that the RONI would have yielded broadly similar declarations to the current system for strong and moderate events — where the warming artefact is small relative to the ENSO signal. The meaningful differences arise for borderline events, which are precisely the cases where miscommunication is most consequential. As documented for 2016/17, earlier and clearer La Niña declarations based on the RONI could have supported more proactive preparedness messaging.

Lucas et al. (2023), in a formal review of BOM's ENSO Alert System, explicitly recommended adopting the RONI alongside an updated 1991–2020 SST climatology. The climatology should be updated at minimum every ten years going forward, in line with WMO recommendations — while recognising that even a regularly updated climatology will always lag the current climate state by up to fifteen years, making the RONI's real-time adjustment increasingly valuable over time.

Seasonal forecast skill

A natural concern about adopting any new index is whether it can be predicted as skillfully as the established one. Van Oldenborgh et al. (2021) and L'Heureux et al. (2024) both evaluated this question rigorously using state-of-the-art seasonal forecast systems: the ECMWF SEAS5 and S4 models, the six-model North American Multi-Model Ensemble (NMME), and BOM's ACCESS-S2 coupled model.

Teleconnections and impact-based forecasting

Perhaps the most operationally valuable property of the RONI is its improved relationship with the regional climate impacts that users need to anticipate. ENSO's primary value to decision-makers lies not in the index value itself, but in its correlation with rainfall, temperature, and extreme event frequency in specific regions. An index that more cleanly isolates the ENSO signal should, in principle, produce sharper and more reliable teleconnection relationships — and this is precisely what the evidence shows.

For Australia during June–August — the austral winter season when ENSO's influence on eastern Australian rainfall peaks — the RONI explains approximately 5–10% more of the interannual precipitation variance than the ONI across Queensland and New South Wales. This improvement is not only statistically meaningful but practically significant: it corresponds to more confident seasonal outlooks for agricultural planning, water storage management, and bushfire risk assessment. Similar improvements are found for the contiguous United States during January–March, particularly across the southwestern states where El Niño-driven winter rainfall is an important resource.

The mechanism behind these improvements is clear: by removing the warming component from the ONI, the RONI better captures the atmospheric circulation changes — particularly shifts in the Walker circulation and the tropical Pacific precipitation dipole — that drive the downstream teleconnections. The warming signal, when present in the ONI, adds noise to the teleconnection rather than ENSO signal.

Communication and decision-relevance

A monitoring index is only valuable insofar as it supports sound decisions. One of the most persistent challenges in ENSO communication is the disconnect between index values and observed impacts. When a “strong” El Niño produces impacts consistent with a moderate event—or a “weak” La Niña generates moderate impacts—user confidence in the monitoring system, and in the seasonal forecasts built upon it, is eroded.

By better aligning the signal with observed outcomes, the RONI has the potential to reduce this mismatch and strengthen the credibility and usability of ENSO-based early warnings.

By providing a more physically consistent measure of ENSO intensity, the RONI can help close this gap. It does not eliminate uncertainty — ENSO teleconnections are inherently probabilistic, and event-to-event variability in impacts is substantial — but it removes a systematic bias that has progressively worsened as the climate has warmed. Used in parallel with the ONI during any transition period, it can also help explain apparent discrepancies between the two measures, providing a richer picture of ENSO conditions for sophisticated users.

Practical Recommendation

For agencies and users relying on ENSO indices for planning and early action, the practical recommendation is:

- Adopt the RONI as the primary operational index for real-time monitoring and prediction.
- Retain the ONI for continuity and communication with established audiences.
- Update the SST climatology to 1991–2020 immediately and commit to updating it at least every ten years thereafter.

Key takeaway

The shift from ONI to RONI is not merely methodological — it is conceptual. It represents a move from measuring absolute ocean temperatures against an ageing historical baseline, to measuring climate-relevant anomalies against the contemporary state of the tropical oceans.

The ONI was designed for a stable climate. The RONI is designed for the climate we have — one that is warming, in which background SST trends must be removed to better isolate the ENSO signal. Both the scientific evidence and the operational track record support this transition.

In a warming world, relative metrics like the RONI are not optional refinements — they are necessary foundations for ENSO monitoring that is scientifically sound, operationally reliable, and genuinely decision-relevant.

Key References

Van Oldenborgh, G.J., Hendon, H., Stockdale, T., L'Heureux, M., Coughlan de Perez, E., Singh, R. & van Aalst, M. (2021). Defining El Niño indices in a warming climate. Environmental Research Letters, 16, 044003. https://doi.org/10.1088/1748-9326/abe9ed

L'Heureux, M.L., Tippett, M.K., Wheeler, M.C., Nguyen, H., Narsey, S., Johnson, N., Hu, Z-Z., Watkins, A.B., Lucas, C., Ganter, C., Becker, E., Wang, W. & Di Liberto, T. (2024). A Relative Sea Surface Temperature Index for Classifying ENSO Events in a Changing Climate. Journal of Climate, 37(4), 1197–1211. https://doi.org/10.1175/JCLI-D-23-0406.1

Turkington, T., Timbal, B. & Rahmat, R. (2019). The impact of global warming on sea surface temperature based El Niño–Southern Oscillation monitoring indices. International Journal of Climatology, 39(2), 1092–1103. https://doi.org/10.1002/joc.5864

Lucas, C., Wheeler, M.C., Nguyen, H., Watkins, A.B., Chua, Z-W. & Ganter, C. (2023). Revising the Bureau's ENSO Alert System: Adapting Indices in a Changing Climate. Bureau of Meteorology Research Report No. 083. Australian Bureau of Meteorology.

Tippett, M. K., Becker, E. J., Camargo, S. J., García-Franco, J. L., Lee, C.-Y., & L'Heureux, M. L. (2025). Relation of Atlantic tropical cyclone activity with observed and predicted ENSO indices. Geophysical Research Letters, 52, e2025GL119286. https://doi.org/10.1029/2025GL119286

Sabeerali, C.T., Sreejith, O.P., Rohini, P. et al. Revisiting ENSO Variability in Indian Summer Monsoon Rainfall: A Comparison of the Oceanic Niño Index (ONI) and the Relative Oceanic Niño Index (RONI). Theor Appl Climatol 157, 186 (2026). https://doi.org/10.1007/s00704-026-06160-8