NIWA

Taihoro Nukurangi

Climate, Freshwater & Ocean Science

# Tokelau Meteorological Service (TMS) training on National Climate Outlook Forums (NCOF)

Tuesday 1 April 2025
NIWA Auckland

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Climate, Freshwater & Ocean Science

NIWA
Taihoro Nukurangi

# Agenda

- **Introductions**
- **National Climate Outlook Forums (NCOFs)**
- **Climate monitoring and forecasting**
- **Seasonal Climate Forecasting**
- **General Circulation Models (GCMs), ensemble and multi-model ensembles (MME)**
- **ENSO**
- **Data source and methodologies for the Tokelau NCOF climate products page**

# A bit about myself

- Dr. Nicolas (*Nico*) Fauchereau
- Principal Scientist, Climate and Analytics at NIWA
- Ph. D in France in 2004 (!), Southern Africa climate variability
- Dept. of Oceanography, University of Cape-Town, South Africa
- Joined NIWA in 2012
- *Seasonal climate forecasting*: NZ’s Seasonal Climate Outlook, and the Island Climate Update (ICU)
- Machine Learning, Open-Source Software, Scientific Programming

# NCOFs (National Climate Outlook Forums)

# What are NCOFs ?

- World Meteorological Organization (WMO) initiatives designed to help countries effectively utilise climate information services
- Services encompass the creation and dissemination of historical, real-time, and prospective climate data
- Aims of NCOFs are to connect climate information generated by National Meteorological and Hydrological Services (NMHSs) with stakeholder and assist their decision-making processes
- WMO's "Step-by-Step Guidelines for Establishing a National Framework for Climate Services" and "Guidance on Good Practices for Climate Services User Engagement" both strongly advocate for the regular implementation of NCOFs as crucial mechanisms for engaging with stakeholders

# What are NCOFs ?

- NCOFs are typically held once or twice per year preceding seasons that are critical for socio-economic sectors, such as rainy or dry seasons. Additional sessions may be organised focusing on specific sectors based on user requirements

# What is the ‘standard’ programme for an NCOF ?

- Discussion of the **current climate**, drawing on national **climate monitoring products**.
- Review of the performance of the seasonal forecast issued in the previous season (“validation”, or “verification”)
- Reports on actions taken by user agencies.
- Delivery of the current **seasonal climate outlook**, along with a discussion of potential impacts and preparedness measures.
- Identification of areas for improvement and actions to address gaps in preparation for the coming season, based on user feedback.
- Discussion of special topics and current issues of interest, if relevant

# What is the outcome expected from a NCOF ?

**standardised and user-friendly production of climate information and products,** including a seasonal outlook.

A **sustainable platform for communication** of information to users and for obtaining their feedback on the usefulness and understanding of products.

**Improved understanding** by users of the information communicated by NMHSs.

**Improved understanding of users' needs** in terms of how information is presented and communicated (formats, standards, visual interpretation, etc.

# Challenges identified

→ Lessons learned from NCOFs held in Papua New Guinea, Kiribati, and Vanuatu …

**PICS panel report** (by Dr. Andrew Tait, Chief Scientist at NIWA)

"Lessons Learned from NCOFs in the Pacific Islands Region"

PICS Panel Report 4 Lessons Learned from NCOFs in the Pacific Islands Region.pdf

- **High costs** associated with planning and running an NCOF
- Maintaining continuity of participants
- Ensuring effective dissemination of information to communities is challenging
- Obtaining feedback on the usefulness of climate information and forecasts can be difficult
- A general challenge exists in ensuring stakeholders have a clear understanding of the **distinctions between weather, climate variability, and climate change**
- **Planning for such a large event requires a long lead time** to manage administrative processes

# Climate Monitoring and Forecasting

# Climate Monitoring

• Climate monitoring involves the **systematic observation and collection of data** related to the climate. This includes meteorological and oceanographic data such as rainfall, temperature, wind, and ocean conditions

• It focuses on tracking **current climate conditions** and the **evolution of climate variability and change**. This can involve monitoring large-scale phenomena like El Niño and La Niña (ENSO)

• Climate monitoring utilizes various **observing systems**, including satellites, buoys, and other instruments operated by National Meteorological and Hydrological Services (NMHSs)

• The data gathered through climate monitoring is used to generate various **climate information products**, such as climate bulletins, **rainfall monitoring data**, and updates on significant climate drivers. These products can be used in discussions at National Climate Outlook Forums (NCOFs) to assess the **current climate**

• Information from climate monitoring is crucial for **understanding prevailing climate conditions** and setting the context for **seasonal forecasts**. It also contributes to **risk management** and the development of **climate services**

• Regional Climate Centers (**RCCs**) are specifically designated to conduct **monitoring activities** as part of their function

→ https://sprep.pda.devopsites.com/
→ https://sprep.pda.devopsites.com/services/node-climate-monitoring

# Climate Forecasting

- Climate forecasting involves **predicting the state of the climate system for a future period**, typically on seasonal to longer timescales. **This goes beyond short-term weather predictions**.

- These forecasts are **probabilistic in nature**, reflecting the inherent uncertainties in predicting complex climate patterns. They often express the likelihood of different climate outcomes, such as temperature or precipitation being above, below, or near normal.

- Climate forecasting utilizes **scientific methods**, including **dynamical climate models** (which simulate the physical processes of the climate system) and **empirical methods** (which use statistical relationships between climate variables).

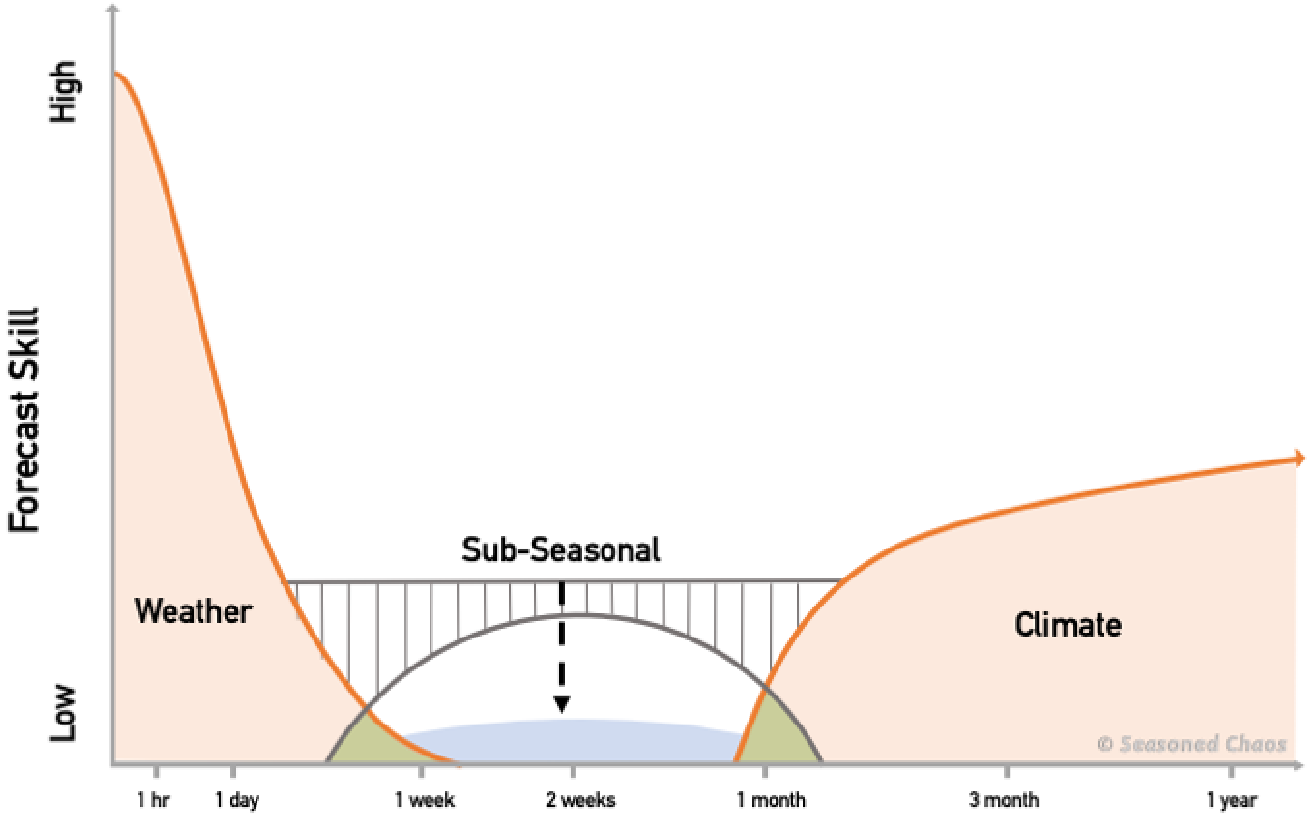
- A key purpose of climate forecasting is to provide **advance information** that can be used for **decision-making** across various socio-economic sectors such as agriculture, water management, health, energy, and disaster risk reduction.

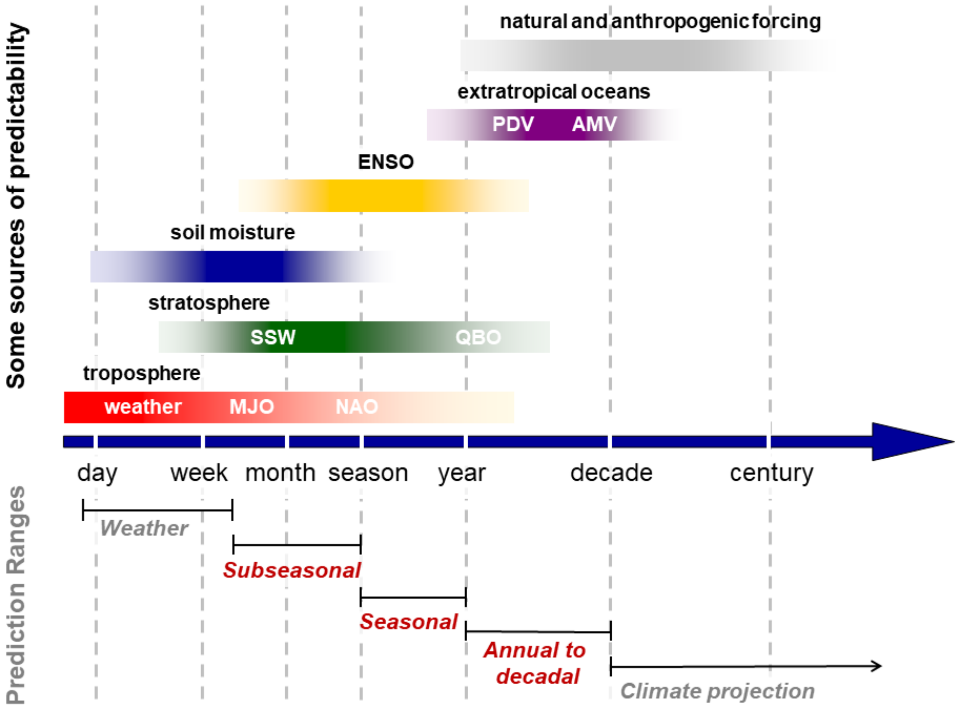
- The skill and reliability of climate forecasts are crucial and are assessed through the analysis of **hindcasts** (forecasts for past periods) and the **verification** of real-time forecasts against observations.

- Climate forecasts are often expressed as **anomalies** relative to a standard reference period, allowing users to understand the expected deviation from typical climate conditions.

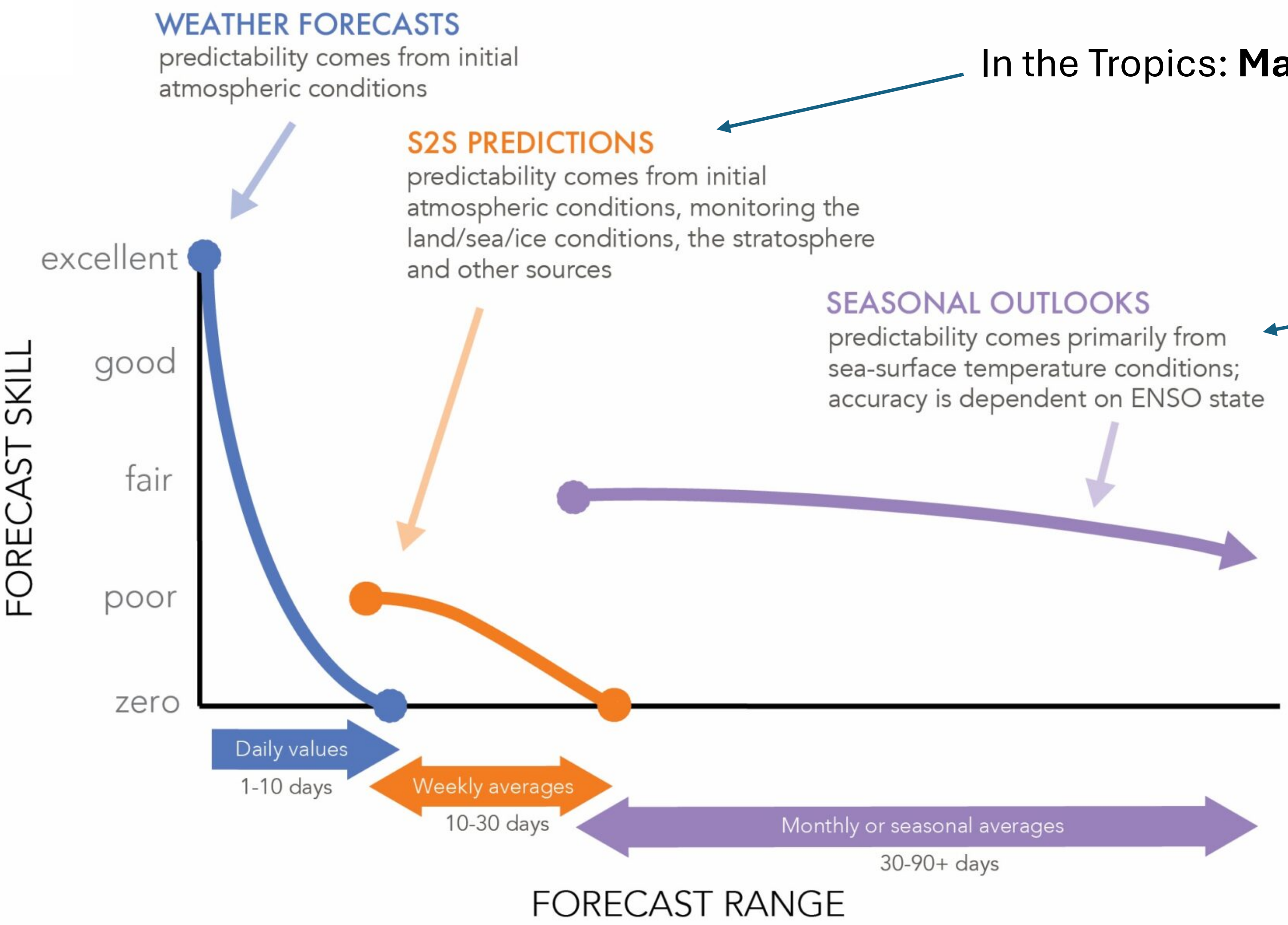
- NCOFs and Regional Climate Outlook Forums (RCOFs, such as PICOF) are important as a way to develop **communication and engagement with users**, and ensure the information is understood and tailored to their needs.

# Weather, seasonal and sub-seasonal time-scales and predictability



# Weather, seasonal and sub-seasonal time-scales and predictability

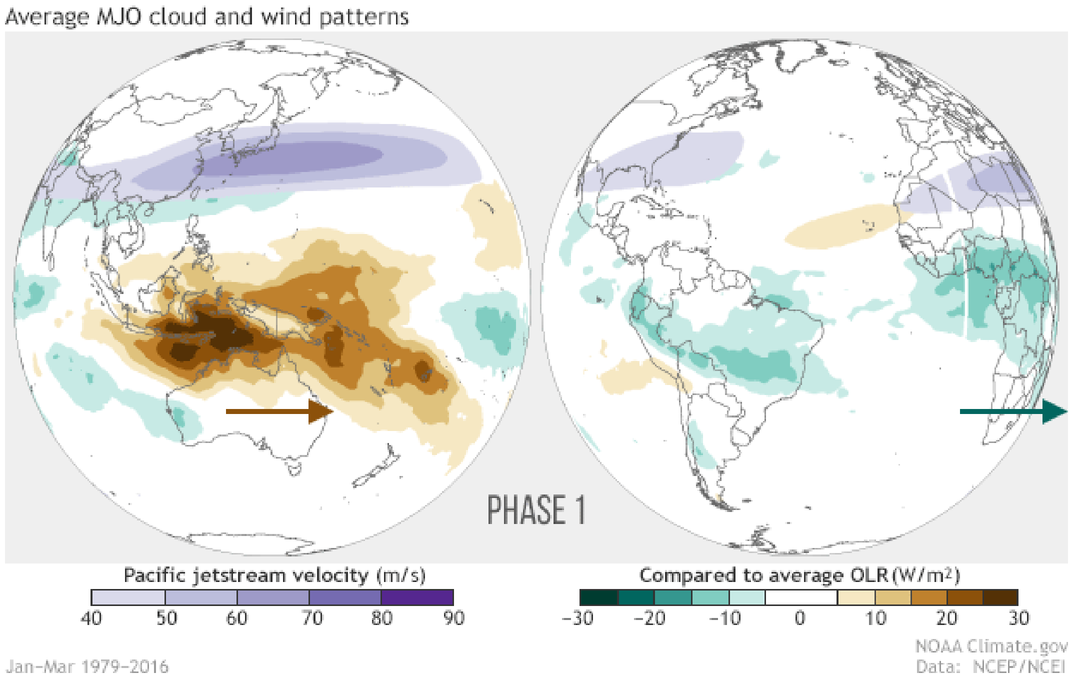


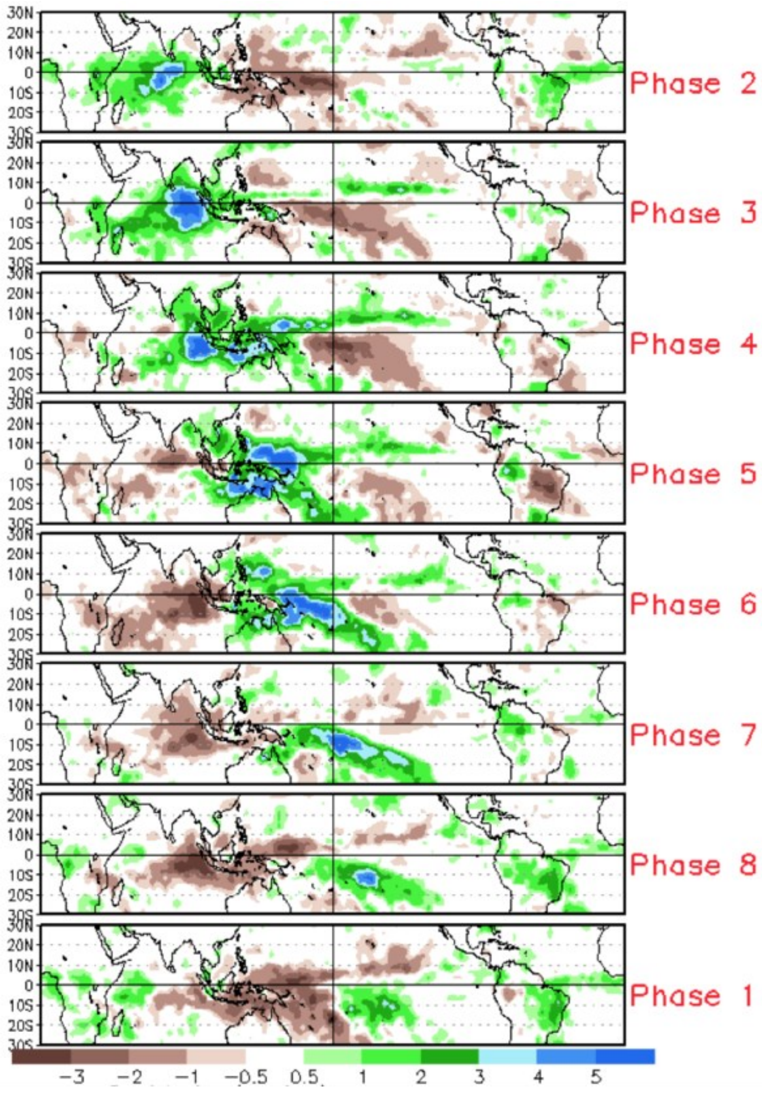

In the Tropics: **Madden-Julian-Oscillation (MJO)**

SSTs (Sea Surface Temperatures)
**ENSO**

# Weather, seasonal and sub-seasonal time-scales and predictability

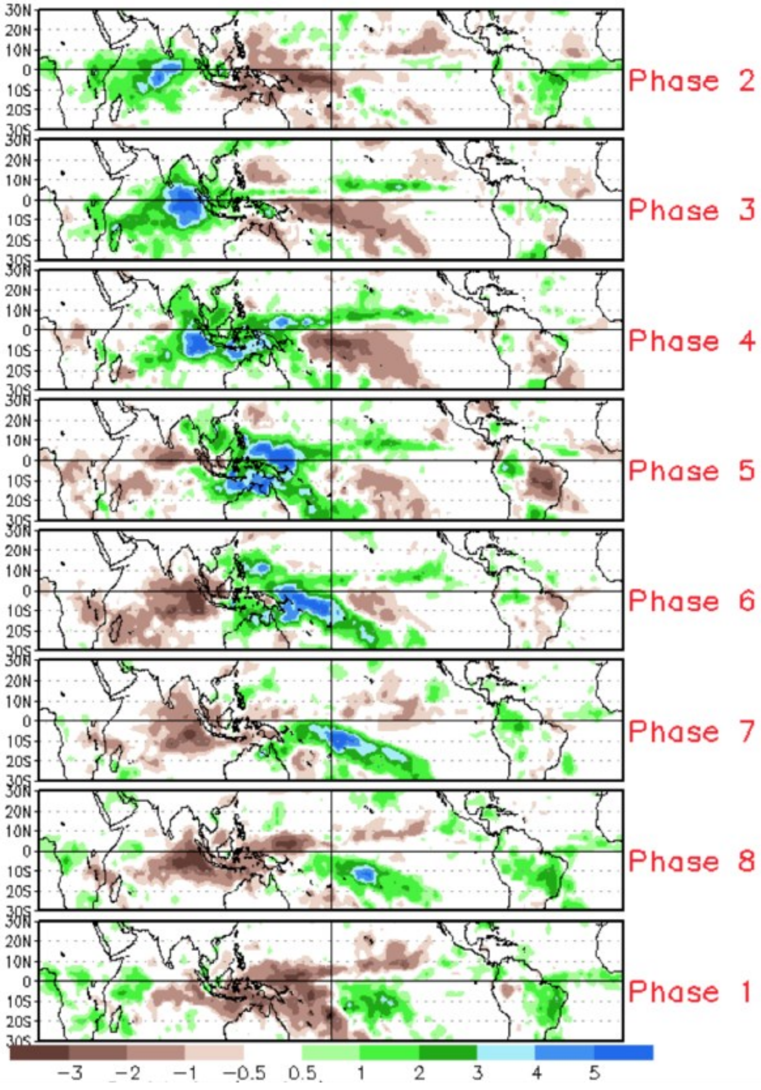
In the Tropics: **Madden-Julian-Oscillation (MJO)**

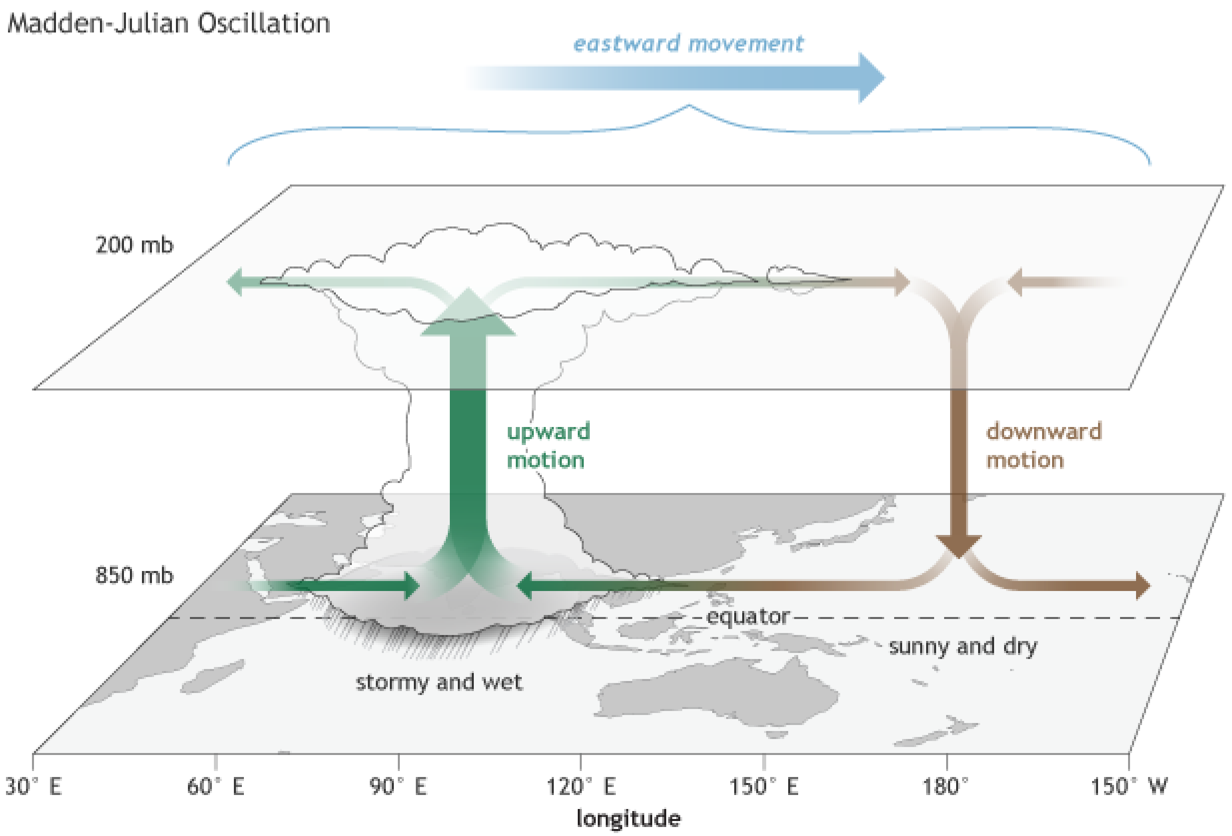


# Weather, seasonal and sub-seasonal time-scales and predictability

In the Tropics: Madden-Julian-Oscillation (MJO)




https://www.climate.gov/news-features/blogs/enso/what-mjo-and-why-do-we-care

# Seasonal climate forecasting

Methods used in seasonal forecasting: **empirical (or statistical)**, **dynamical**, and **hybrid**.

## Empirical Seasonal Forecast Methods

Rely on **statistical relationships identified from historical observational data** between predictor variables and the variable being forecast (the predictand). Typically, this involves some form of **regression model**.

For example, the **Niño-3.4 Index** (a predictor) might be used to forecast seasonal mean surface temperature (the predictand).

Predictors are usually chosen based on a physical understanding of the factors influencing the predictand. Many Regional Climate Outlook Forums (RCOFs) use observed tropical ocean Sea Surface Temperatures (SSTs) from the previous month to forecast precipitation and surface land temperatures for the upcoming season.

**Advantages:**

**low computational resource requirements** and ease of operational implementation.

They are also inherently **consistent with observations** (bias-corrected with respect to the mean) and can provide both deterministic and probabilistic forecasts.

**Disadvantages:**

Assumption of **stationarity in the climate system**, which means they may not adequately represent trends. They can also struggle to reproduce the observed variance and may not capture non-linear interactions effectively.

It is anticipated that dynamical models will become more effective than empirical methods in the future.

The evaluation of statistical models requires a **cross-validation approach** to ensure fair estimates of forecast quality. Tools like the **IRI's Climate Predictability Tool (CPT)** are widely used for empirical prediction.

SCOPIC has been widely used in the Pacific and relies on relationships between rainfall and ENSO indicators

Methods used in seasonal forecasting: **empirical (or statistical)**, **dynamical**, and **hybrid**.

## Dynamical Seasonal Forecasting

Use **global climate models (GCMs)** to predict future climate conditions. There are two main approaches:

**Two-Tier System Approach**: An **atmospheric Global General Circulation Model (AGCM)** is forced at its lower boundary using either **persisted** or **predicted SST anomalies**. For example, observed SST anomalies from the previous month might be added to climatological SSTs for the forecast period. This approach is most useful for **short lead time predictions**

**One-Tier System Approach**: A **coupled ocean-atmosphere Global General Circulation Model (CGCM)** is used to generate predictions, typically for up to 6-12 months ahead. In this approach, both the ocean and atmosphere are initialised, often with small differences to create an **ensemble of predictions**, allowing for the sampling of initial state uncertainties. Coupled systems are increasingly favoured as they can represent **two-way air-sea interactions**, which are crucial for seasonal forecasting. Most Global Producing Centres for Long-Range Forecasts (GPCs-LRF) now use the one-tier approach.

**Advantages:**

An important advantage of dynamical methods is the availability of **ensembles**, which allows for better quantification of forecast uncertainty and the generation of probabilistic forecasts.

They can also simulate non-linear components of teleconnections.

Do not assume stationarity

**Disadvantages:**

**Costly** ! Require high performance computer

**Complex** to maintain and update.

**Diases** in the representation of mean and variance of variables like precipitation and cloudiness, as well as in spatial patterns.

Evaluating these biases through **hindcasts** adds to the cost and complexity.

# Hybrid methods

**Combine elements of both dynamical and statistical methods**.

often by using **statistical techniques to bias-correct and calibrate dynamical model outputs**.

For example, statistical relationships between predicted model variables (related to large-scale climate modes like ENSO) and observed variables in a region of interest can be used to enhance the skill of real-time dynamical predictions.

Hybrid methods can also implicitly perform **downscaling** to the resolution of observational datasets.

**Downscaling**: map low-resolution outputs of the GCMs (typically ~ 1o) to high resolution observational datasets

Empirical prediction systems can also be used to improve model combinations (→ *when utilizing a multi-model ensemble forecast approach*).

# NOTE

In developing seasonal forecasts, the selection of appropriate models (empirical or dynamical) and the combination of forecasts from multiple sources (multi-model ensembles) are important considerations.

**Hindcasts** play a crucial role in assessing the skill of different forecasting systems and in performing **bias correction and calibration**.

Seasonal forecasts are often presented in a **probabilistic format**, such as the probability of exceeding certain thresholds or the probability of falling into tercile categories (above normal, near normal, below normal).

**Tailoring** these forecasts to specific user needs and sectors is also a key aspect of making them more useful for decision-making.

# GCMs, ensembles and multi-model ensembles

# What are General Circulation Models (GCMs) ?

• GCMs are **state-of-the-art computer climate models** used for seasonal prediction.

•These are **global models** that produce forecast information for the entire planet.

• They are **coupled dynamical models**, meaning they consider the interactions between the atmosphere, ocean, land, and cryosphere.

• GCMs use **complex physical equations** to predict future climate conditions.

•These models are **initialized** with a picture of current ocean, atmospheric, and land conditions to start their predictions.

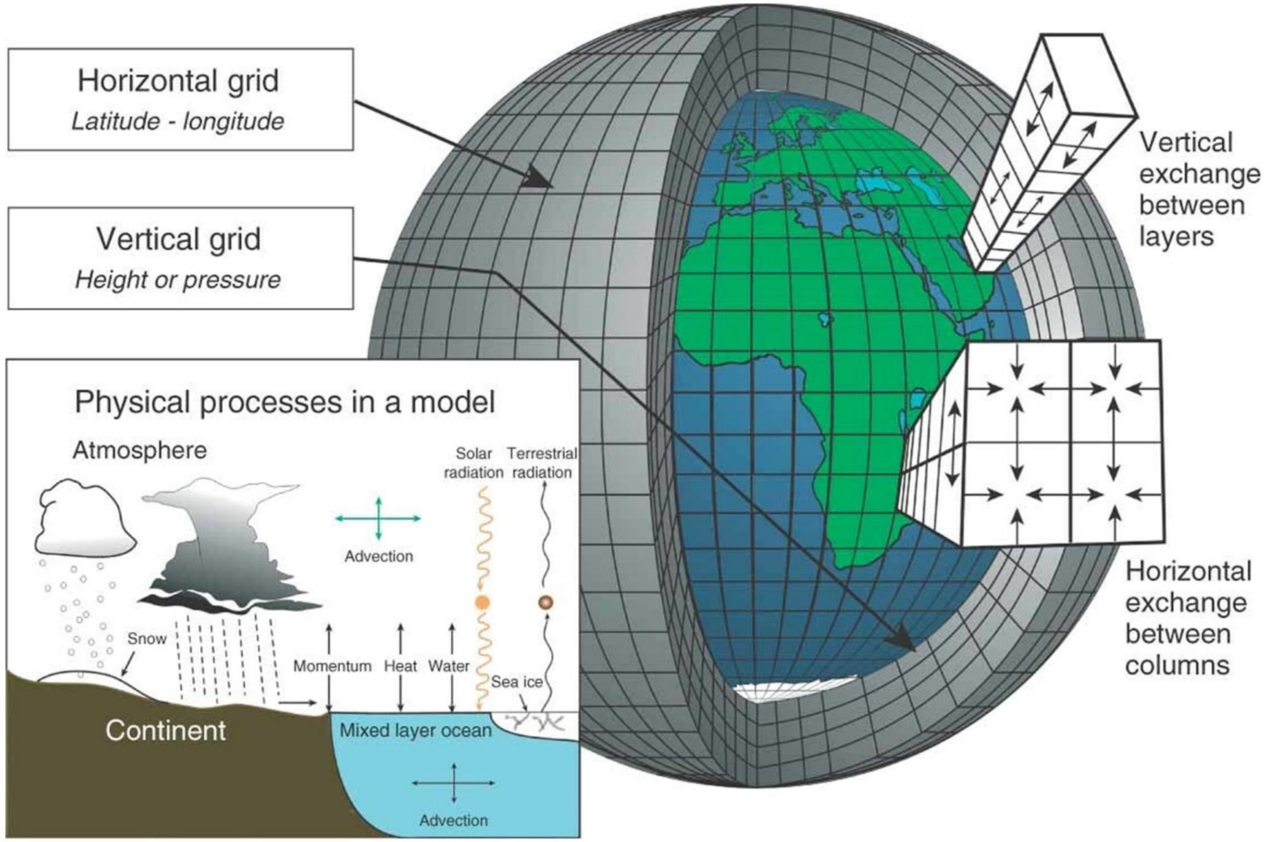
• Dynamical seasonal forecast methods using global climate models are being used with increasing frequency.

• The output from dynamical models can provide forecasts of numerous variables like temperature, precipitation, and soil moisture.

• GCMs form the basis of multi-model ensembles, which generally provide more skilful and reliable forecasts than single models.

• Despite their sophistication, GCMs can have biases, such as the "cold tongue" bias in the equatorial Pacific. Statistical methods can be used to bias-correct and calibrate their outputs.

History of climate modeling - Edwards - 2011 - WIREs Climate Change - Wiley Online Library




$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} - v\frac{\partial u}{\partial y} - \omega\frac{\partial u}{\partial p} + fv - \frac{\partial \phi}{\partial x} + F_x$$

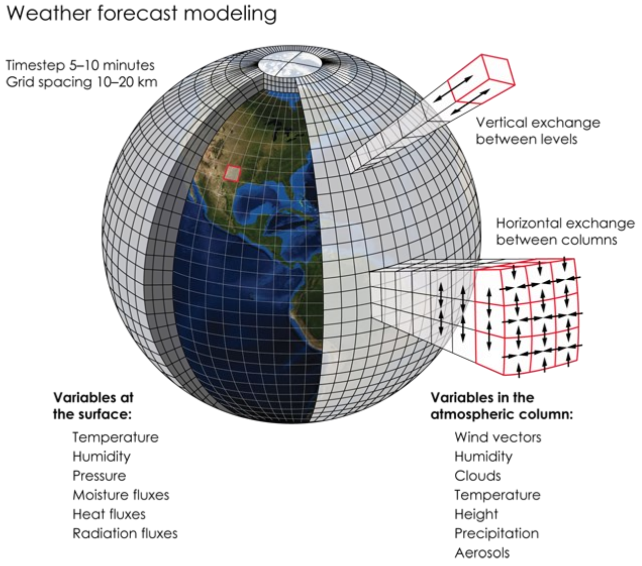
$$\frac{\partial v}{\partial t} = -u\frac{\partial v}{\partial x} - v\frac{\partial v}{\partial y} - \omega\frac{\partial v}{\partial p} - fu - \frac{\partial \phi}{\partial y} + F_y$$

$$\frac{\partial \phi}{\partial p} = -\frac{RT}{p}$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial p} = 0$$

$$\frac{\partial T}{\partial t} = -u\frac{\partial T}{\partial x} - v\frac{\partial T}{\partial y} + \omega\left(\frac{RT}{c_p p} - \frac{\partial T}{\partial P}\right) + \frac{H}{c_p}$$

$$\frac{\partial q}{\partial t} = -u\frac{\partial q}{\partial x} - v\frac{\partial q}{\partial y} - \omega\frac{\partial q}{\partial p} + E - P$$




[History of climate modeling - Edwards - 2011 - WIREs Climate Change - Wiley Online Library]

nature reviews earth & environment



Review Article | Published: 13 April 2021

# Initialized Earth System prediction from subseasonal to decadal timescales

Gerald A. Meehl, Jadwiga H. Richter, Haiyan Teng, Antonietta Capotondi, Kim Cobb, Francisco Doblas-Reyes, Markus G. Donat, Matthew H. England, John C. Fyfe, Weiqing Han, Hyemi Kim, Ben P. Kirtman, Yochanan Kushnir, Nicole S. Lovenduski, Michael E. Mann, William J. Merryfield, Veronica Nieves, Kathy Pegion, Nan Rosenbloom, Sara C. Sanchez, Adam A. Scaife, Doug Smith, Aneesh C. Subramanian, Lantao Sun, ... Shang-Ping Xie + Show authors

*Nature Reviews Earth & Environment* **2**, 340–357 (2021) | Cite this article



## Abstract

Initialized Earth System predictions are made by starting a numerical prediction model in a state as consistent as possible to observations and running it forward in time for up to 10 years. Skilful predictions at time slices from subseasonal to seasonal (S2S), seasonal to interannual (S2I) and seasonal to decadal (S2D) offer information useful for various stakeholders, ranging from agriculture to water resource management to human and infrastructure safety. In this Review, we examine the processes influencing predictability, and discuss estimates of skill across S2S, S2I and S2D timescales. There are encouraging signs that skilful predictions can be made: on S2S timescales, there has been some skill in predicting the Madden–Julian Oscillation and North Atlantic Oscillation; on S2I, in predicting the El Niño–Southern Oscillation; and on S2D, in predicting ocean and atmosphere variability in the North Atlantic region. However, challenges remain, and future work must prioritize reducing model error, more effectively communicating forecasts to users, and increasing process and mechanistic understanding that could enhance predictive skill and, in turn, confidence. As numerical models progress towards Earth System models, initialized predictions are

## (initialised) ensemble forecast systems

**(Initialised) ensemble forecast systems** are a method of generating climate forecasts, particularly seasonal forecasts, that rely on the following key principles:

• **Ensemble of Forecasts:** Rather than producing a single forecast, these systems generate a **collection of multiple forecasts**, known as an **ensemble**. Each individual forecast within the ensemble is often called a "*realization*" or "*member*".

• **Perturbed Initial Conditions:** The different forecasts within an ensemble are created by starting the climate model simulations with **slightly different initial conditions**. These small variations in the initial state of the climate system (e.g., atmospheric temperature, ocean currents, soil moisture) are designed to **sample the inherent uncertainties** in our knowledge of the current climate state. These initial perturbations grow over time due to the chaotic nature of the climate system.

• **Quantifying Uncertainty:** The **spread or divergence among the different members of the ensemble** provides an estimate of the **uncertainty** associated with the forecast. A larger spread indicates greater uncertainty, while a smaller spread suggests more confidence in the general outcome.

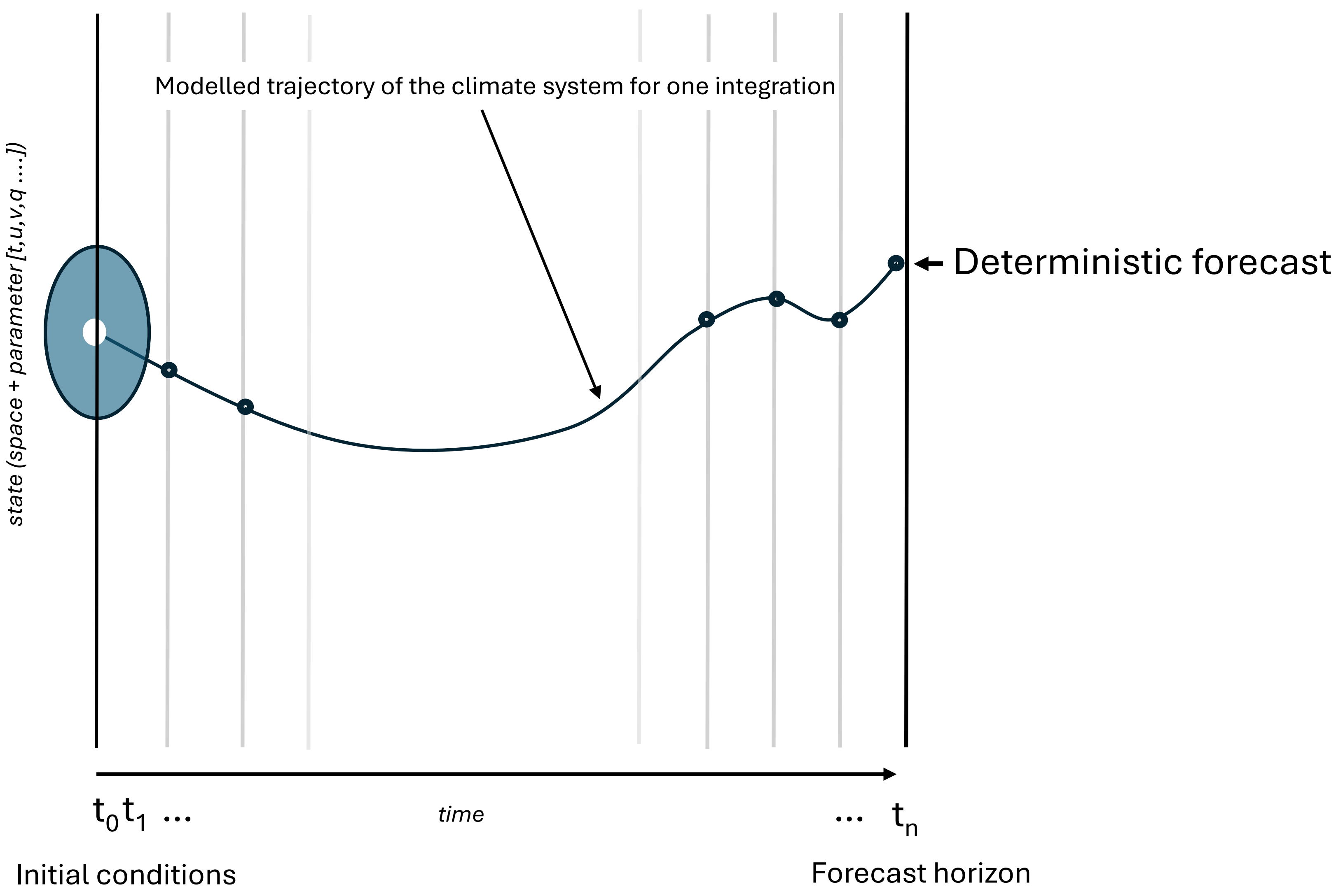
• **Probabilistic Forecasts:** The results from the ensemble forecast are used to **estimate the probabilities of different future climate scenarios**. For instance, they can indicate the likelihood of temperature or precipitation falling within categories (e.g., above normal, near normal, below normal).

• **Initialization with Observations:** The process begins with **initialising the climate model** using comprehensive **real-time observations** of the Earth system. Data assimilation systems are used to incorporate these observations and create the initial conditions for the model runs. Hindcasts, which are "forecasts" of past climate states, also rely on observational information available at their initial time.

In essence**, initialized ensemble forecast systems acknowledge the inherent unpredictability of the climate system by running multiple model simulations from slightly different starting points** (informed by observations).

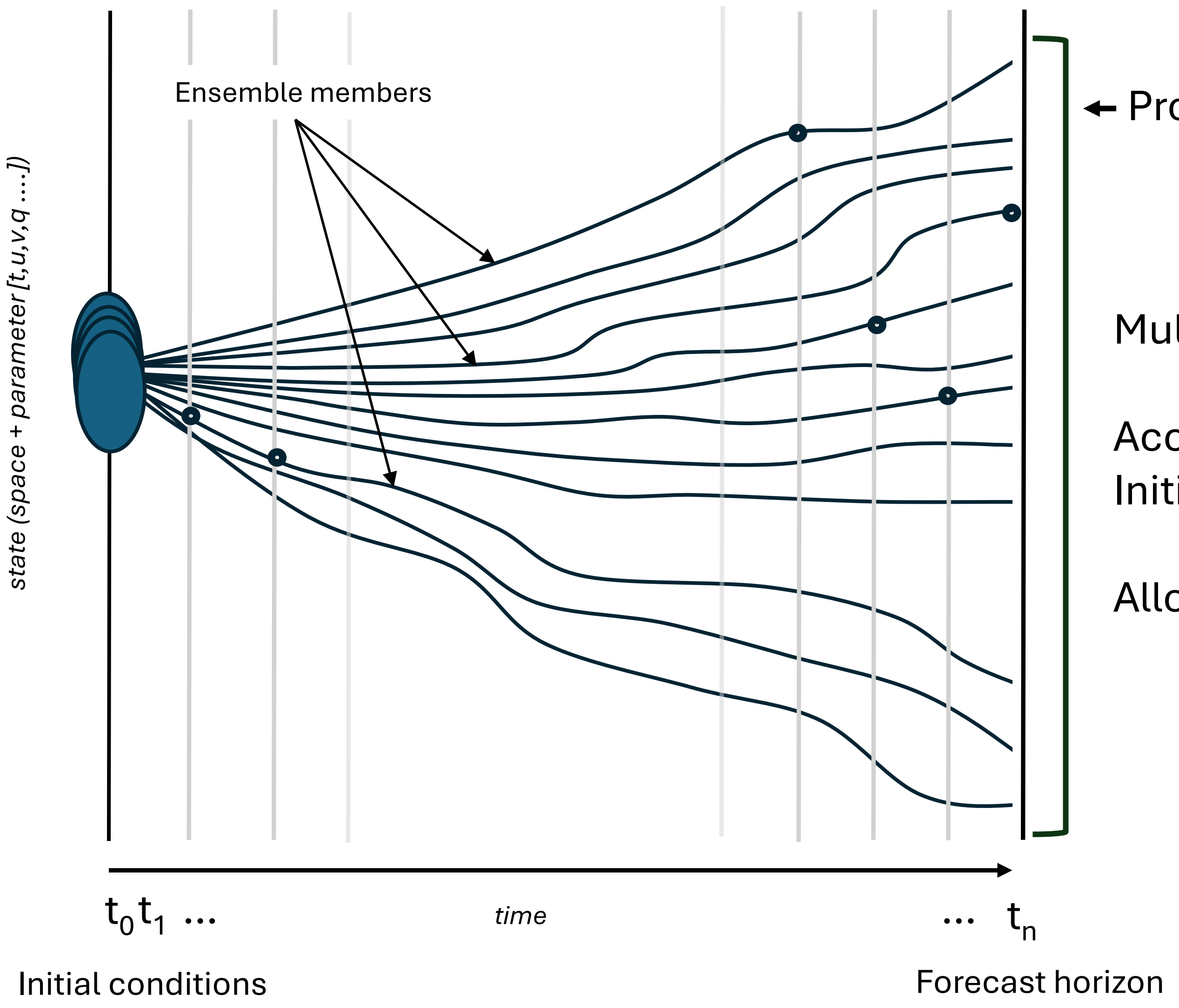
The range of outcomes from these simulations allows for a more complete understanding of the potential future climate and provides a basis for **probabilistic forecasting** and the quantification of forecast uncertainty.

These systems are increasingly preferred for seasonal forecasting as they can represent complex climate interactions and provide valuable information for decision-making across various sectors.



state (space + parameter [t,u,v,q ...])
Modelled trajectory of the climate system for one integration
Deterministic forecast
$t_0$ $t_1$ ...
time
... $t_n$
Initial conditions
Forecast horizon

## **Ensemble forecast systems** [ensemble systems underpinning the SCO and ICU]




← Probabilistic forecast

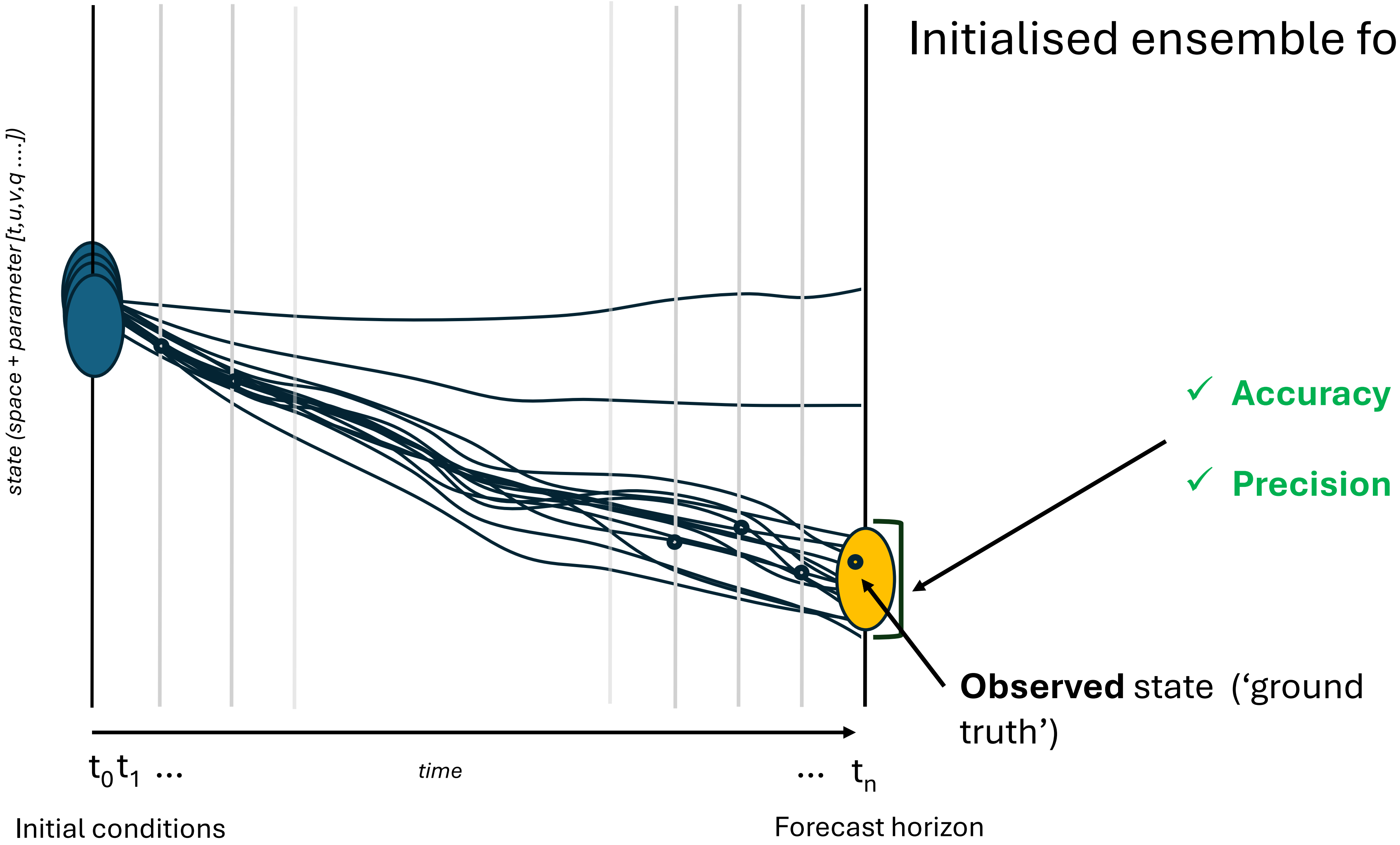
Multiple integrations with slightly *perturbed* initial conditions

Accounts for uncertainties and incompleteness in knowledge of Initial conditions

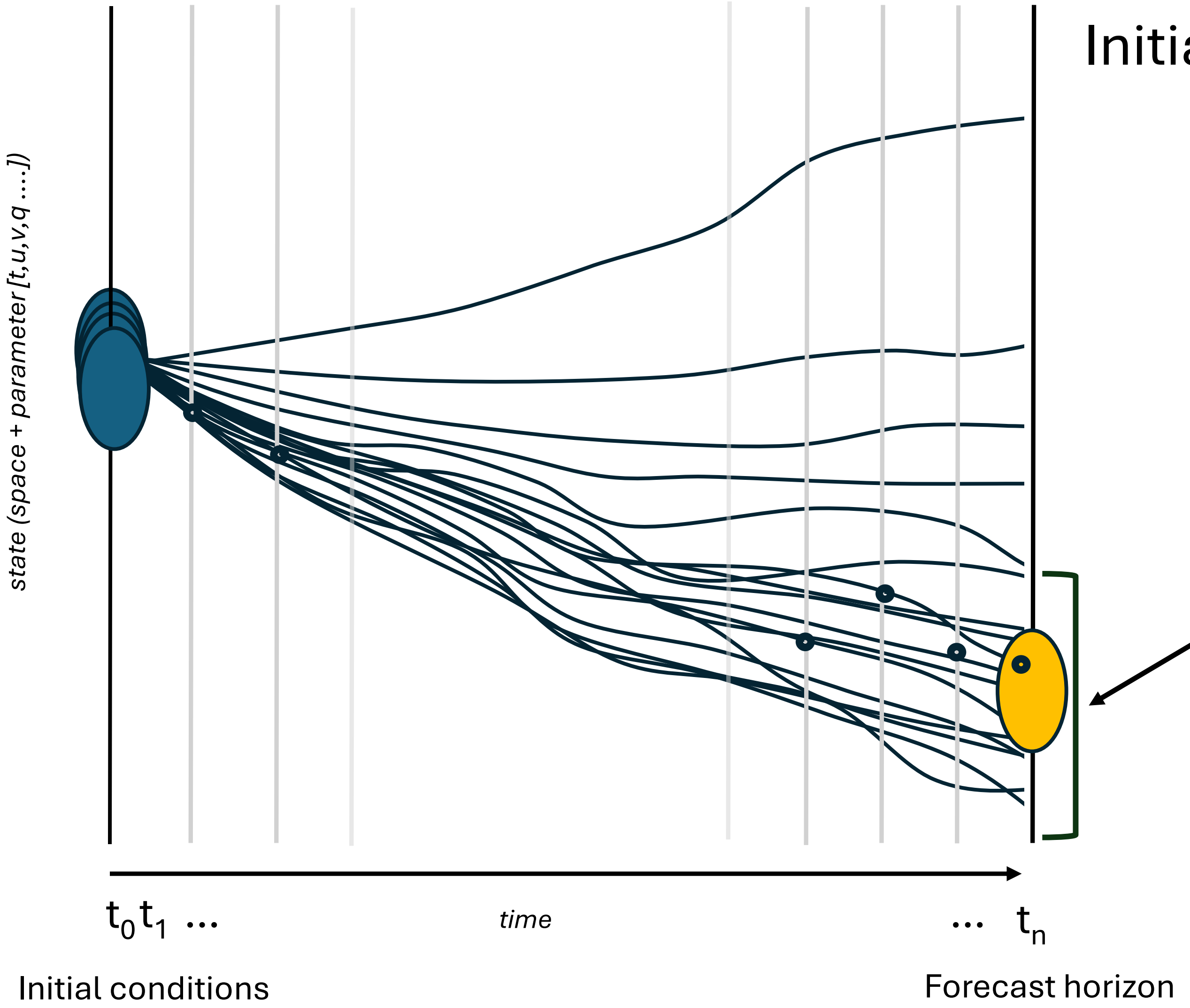
Allows for the provision of **probabilistic** forecasts

## Ensemble forecast systems

Initialised ensemble forecast systems' performanc



**<u>Ensemble</u> forecast systems** [@NIWA: NZ-ENS, NIWA35, ensemble systems underpinning the SCO and ICU]



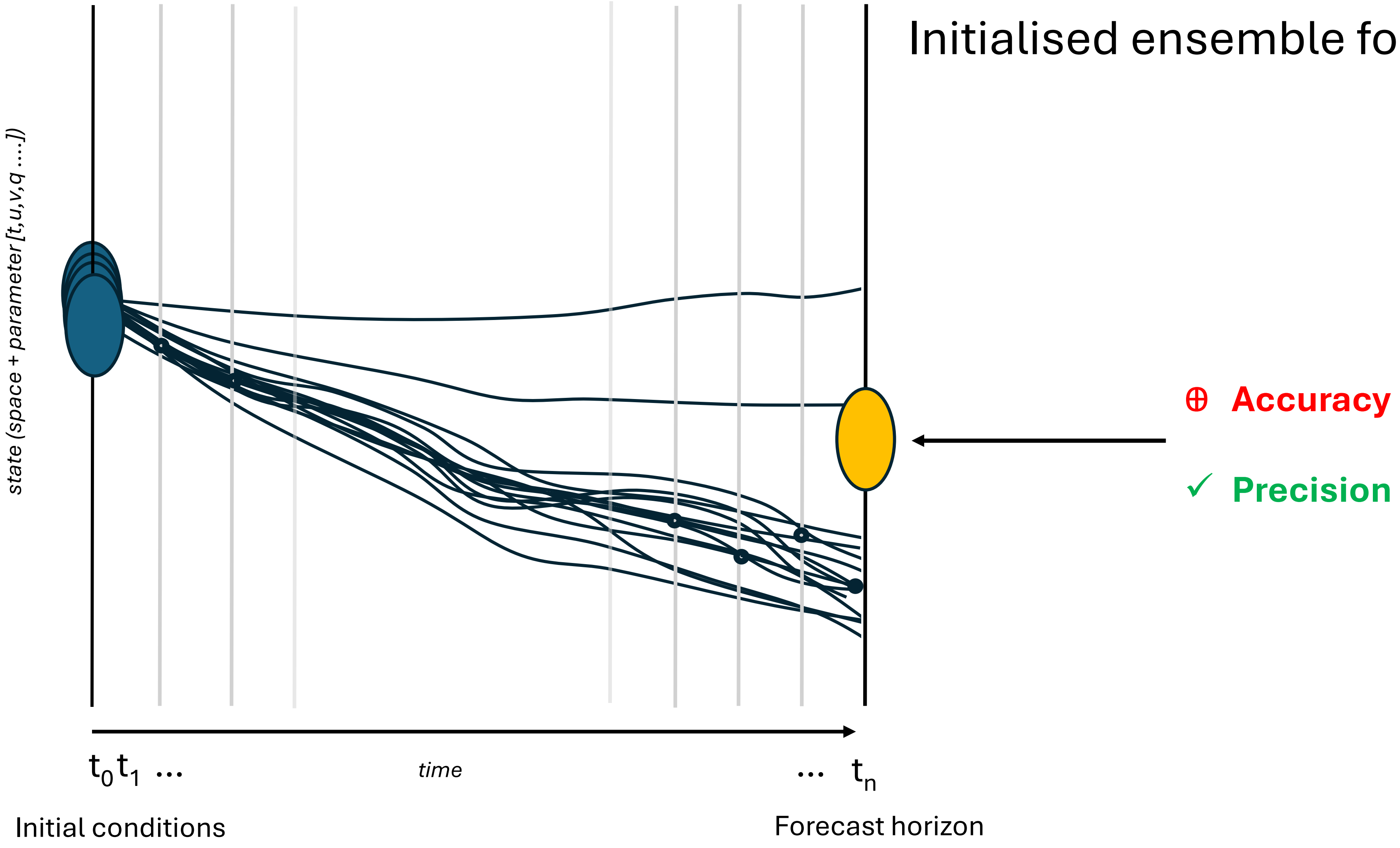

Initialised ensemble forecast systems' performanc

✓ **Accuracy**

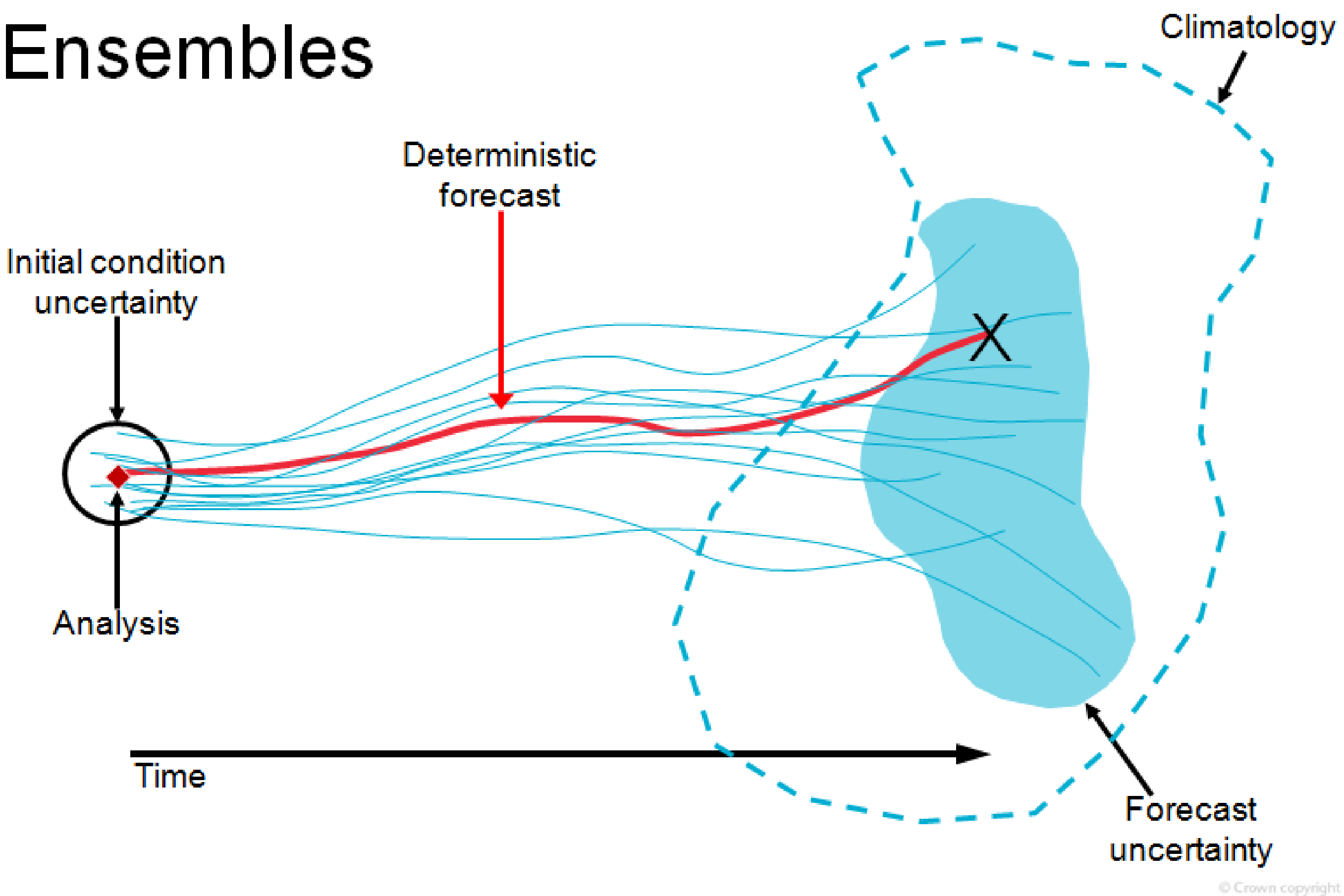
⊕ **Precision**

**<u>Ensemble</u> forecast systems** [@NIWA: NZ-ENS, NIWA35, ensemble systems underpinning the SCO and ICU]

Initialised ensemble forecast systems' performanc



# Ensembles


Climatology
Deterministic forecast
Initial condition uncertainty
Analysis
Time
Forecast uncertainty
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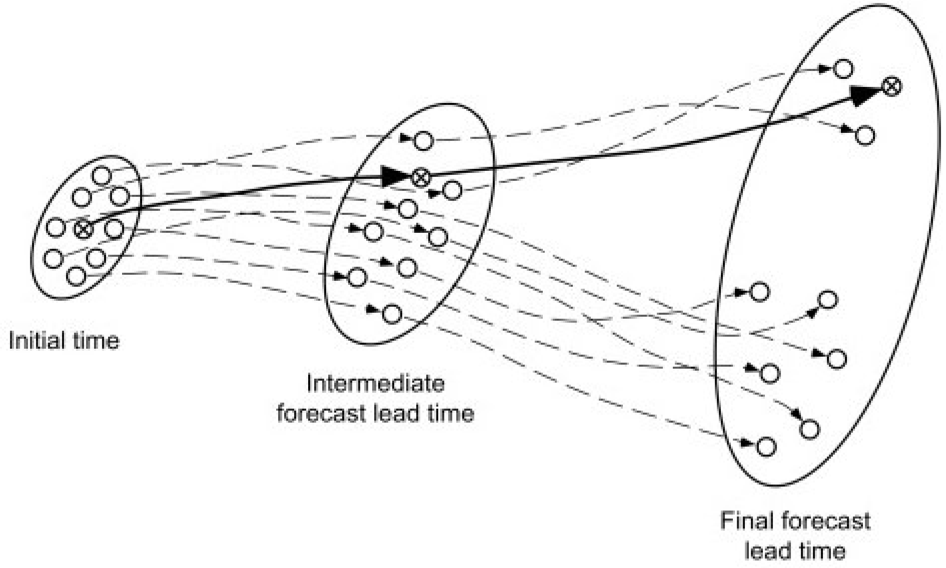
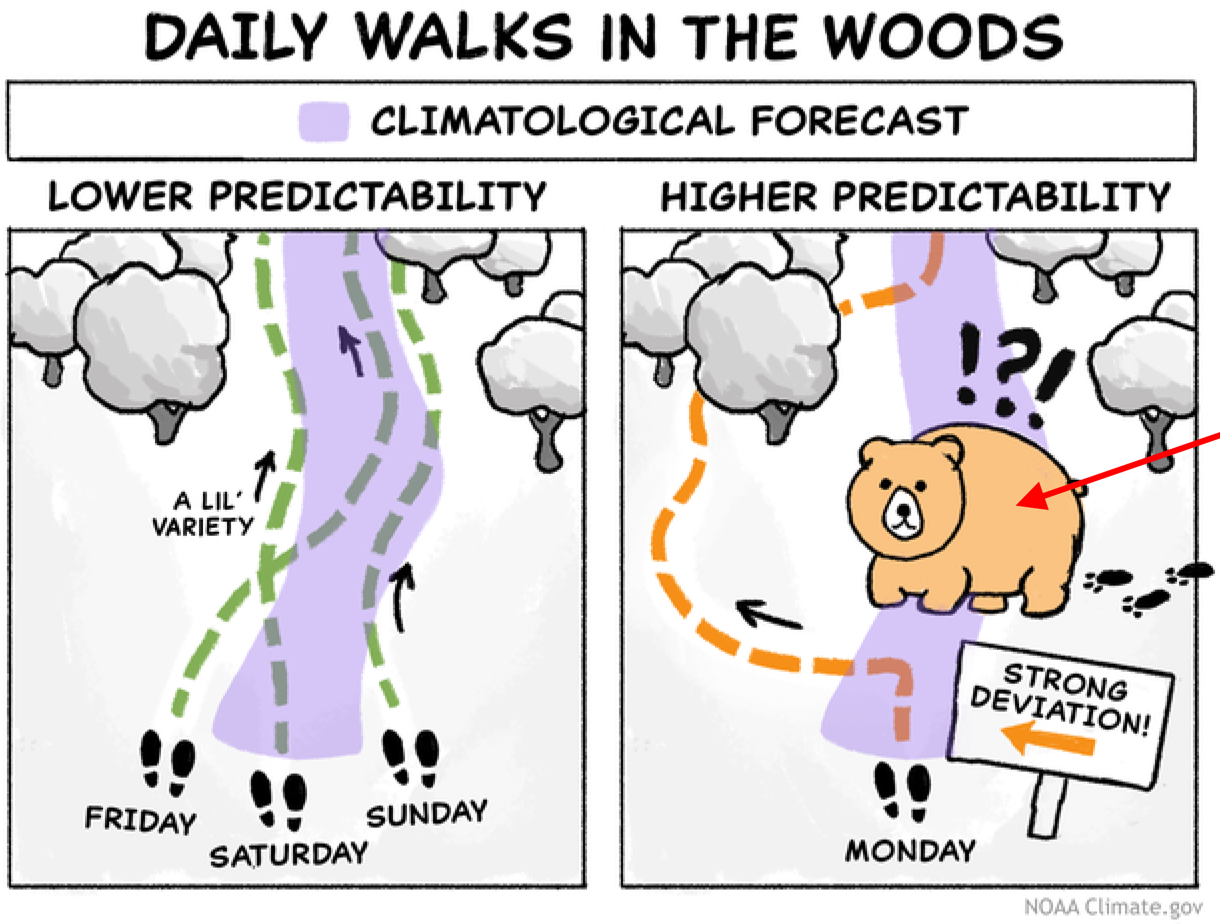
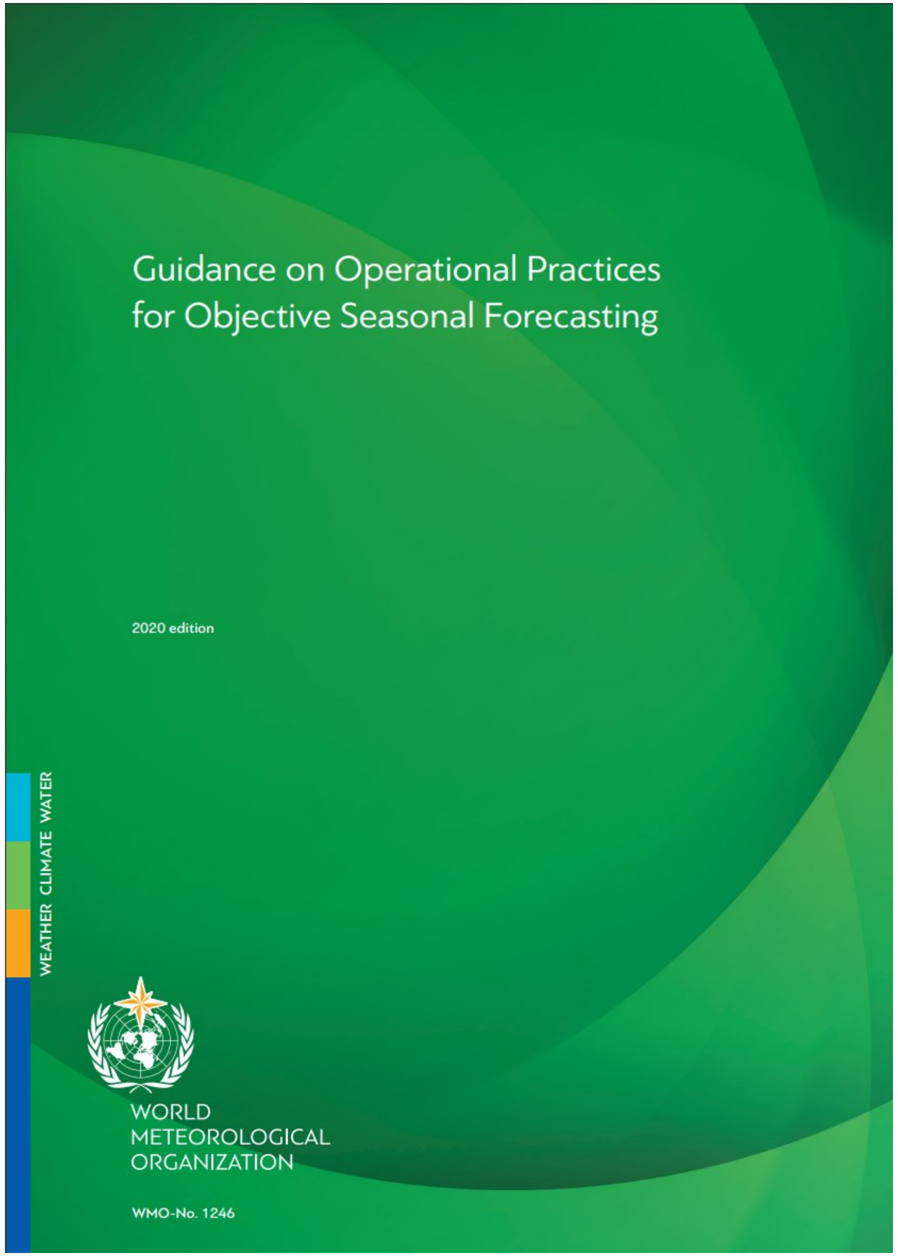

Initial time
Intermediate forecast lead time
Final forecast lead time




The ENSO bear !

## Following the recommendations from the WMO




**p 27.**: "Combining predictions from **different and complementary models** helps improve our predictive ability, and there is documented evidence that an average of forecast inputs (the **multi-model ensemble approach**) is statistically a better predictor of observed climate than a single model alone and makes combining different climate model predictions advantageous and an advisable approach

# Seasonal Forecasts and Outlooks

- Island Climate Update – ICU (NIWA)
  - https://niwa.co.nz/climate-and-weather/island-climate-update
  - https://shiny.niwa.co.nz/icu-app/
- ACCESS-S (BoM)
  - https://access-s.clide.cloud/
- CLIK/PICASO (APCC)
  - https://www.apcc21.org/prediction/global/outlook?lang=en
  - https://library.sprep.org/sites/default/files/application-guideline-ROK-Pi-CliPS.pdf

# About the Island Climate Update

- The Island Climate Update has been generated at NIWA since 1999; originally a multi-organisation consensus product, it is now fully automated and objective.

- NIWA's Island Climate Update integrates both near real-time satellite rainfall monitoring from Multi-Source Weighted-Ensemble Precipitation (MSWEP) and one- and three-month forecasts from the Copernicus Climate Change Service (C3S).

- The system tracks the evolution of several water stress indices and incorporates state-of-the-art probabilistic seasonal forecasts from nine climate models made available on C3S (a 550+ member multi-model ensemble), focusing on the Pacific Islands.

- This approach forms the basis of a paper in review for Climate Services, "Open data and open source software for the development and validation of multi-model monthly-to-seasonal probabilistic forecasts for the southwest Pacific."

- View the preprint here.

- For the latest edition of the Island Climate Update (from this point, ICU), click here.

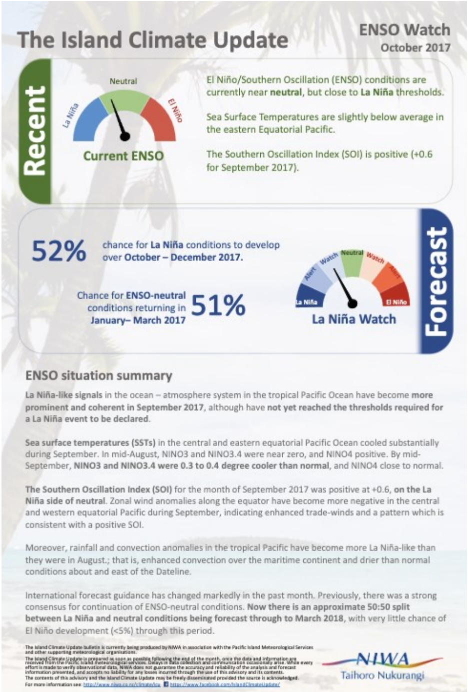
- This slide deck provides some context as to how skilful the ICU forecasts are.

# The Island Climate Update over the years

**2001**


**2007**


**2017**



The Island Climate Update

ENSO Watch
October 2017

**Recent**

Neutral
La Niña
El Niño
Current ENSO

El Niño/Southern Oscillation (ENSO) conditions are currently near **neutral**, but close to **La Niña** thresholds.

Sea Surface Temperatures are slightly below average in the eastern Equatorial Pacific.

The Southern Oscillation Index (SOI) is positive (+0.6 for September 2017).

**Forecast**

52% chance for **La Niña** conditions to develop over **October – December 2017.**

Chance for **ENSO-neutral** conditions returning in **January– March 2017** 51%

La Niña Watch

## ENSO situation summary

**La Niña-like signals** in the ocean – atmosphere system in the tropical Pacific Ocean have become **more prominent and coherent in September 2017**, although have **not yet reached the thresholds required for a La Niña event to be declared**.

**Sea surface temperatures (SSTs)** in the central and eastern equatorial Pacific Ocean cooled substantially during September. In mid-August, NINO3 and NINO3.4 were near zero, and NINO4 positive. By mid-September, **NINO3 and NINO3.4 were 0.3 to 0.4 degree cooler than normal**, and NINO4 close to normal.

**The Southern Oscillation Index (SOI)** for the month of September 2017 was positive at +0.6, **on the La Niña side of neutral**. Zonal wind anomalies along the equator have become more negative in the central and western equatorial Pacific during September, indicating enhanced trade-winds and a pattern which is consistent with a positive SOI.

Moreover, rainfall and convection anomalies in the tropical Pacific have become more La Niña-like than they were in August.; that is, enhanced convection over the maritime continent and drier than normal conditions about and east of the Dateline.

International forecast guidance has changed markedly in the past month. Previously, there was a strong consensus for continuation of ENSO-neutral conditions. **Now there is an approximate 50:50 split between La Niña and neutral conditions being forecast through to March 2018**, with very little chance of El Niño development (<5%) through this period.

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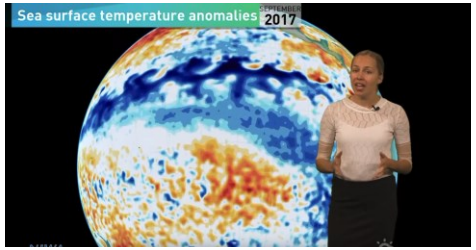
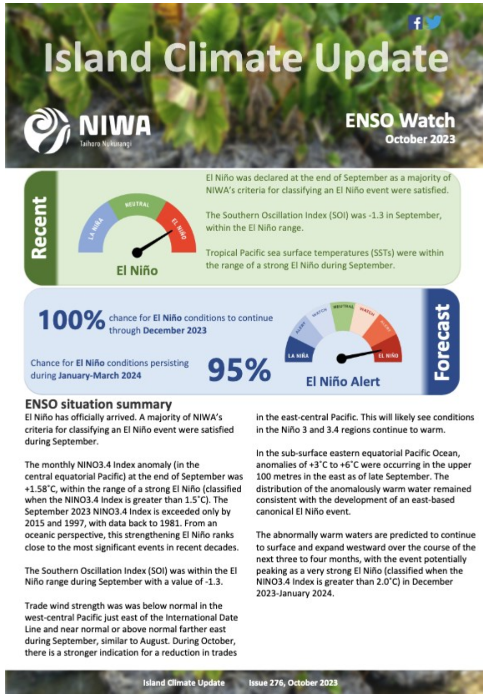



**2023**



Island Climate Update

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ENSO Watch
October 2023

**Recent**

NEUTRAL
LA NIÑA
EL NIÑO
El Niño

El Niño was declared at the end of September as a majority of NIWA's criteria for classifying an El Niño event were satisfied.

The Southern Oscillation Index (SOI) was -1.3 in September, within the El Niño range.

Tropical Pacific sea surface temperatures (SSTs) were within the range of a strong El Niño during September.

**Forecast**

100% chance for **El Niño** conditions to continue through **December 2023**

Chance for **El Niño** conditions persisting during **January-March 2024** 95%

El Niño Alert

## ENSO situation summary

El Niño has officially arrived. A majority of NIWA's criteria for classifying an El Niño event were satisfied during September.

The monthly NINO3.4 Index anomaly (in the central equatorial Pacific) at the end of September was +1.58˚C, within the range of a strong El Niño (classified when the NINO3.4 Index is greater than 1.5˚C). The September 2023 NINO3.4 Index is exceeded only by 2015 and 1997, with data back to 1981. From an oceanic perspective, this strengthening El Niño ranks close to the most significant events in recent decades.

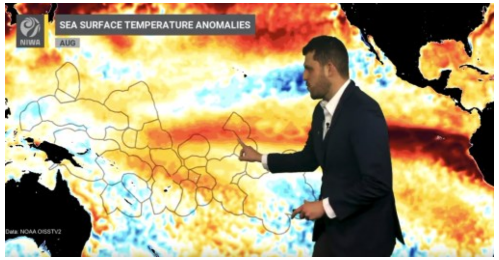
The Southern Oscillation Index (SOI) was within the El Niño range during September with a value of -1.3.

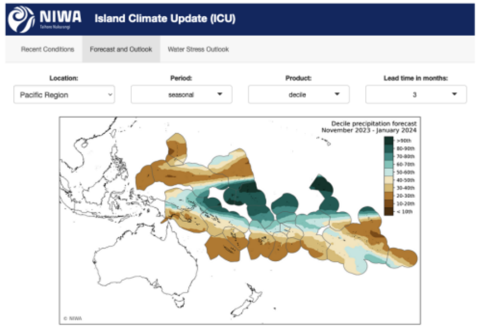
Trade wind strength was was below normal in the west-central Pacific just east of the International Date Line and near normal or above normal farther east during September, similar to August. During October, there is a stronger indication for a reduction in trades in the east-central Pacific. This will likely see conditions in the Niño 3 and 3.4 regions continue to warm.

In the sub-surface eastern equatorial Pacific Ocean, anomalies of +3˚C to +6˚C were occurring in the upper 100 metres in the east as of late September. The distribution of the anomalously warm water remained consistent with the development of an east-based canonical El Niño event.

The abnormally warm waters are predicted to continue to surface and expand westward over the course of the next three to four months, with the event potentially peaking as a very strong El Niño (classified when the NINO3.4 Index is greater than 2.0˚C) in December 2023-January 2024.

Island Climate Update Issue 276, October 2023




# Seasonal forecasts performance

# Forecasts validation / verification

# Forecasts validation / verification

- For Tokelau REALTIME forecast validation / verification will be made available in the next few months

- **Dependencies:**
  - Transition from MSWEP 2.8.0 to MSWEP 3.0 for rainfall monitoring (need updated climatologies)
  - Transition to new NIWA High Performance Computer (Gen 4)

- Validations below are for the period **1993 – 2016**

- Developed as part of the **Island Climate Update (ICU)**

- The TMS product page leverages the same suite of GCMs (the C3S Multi-Model Ensemble)

# Overview: ICU forecast skill in the tropical Pacific

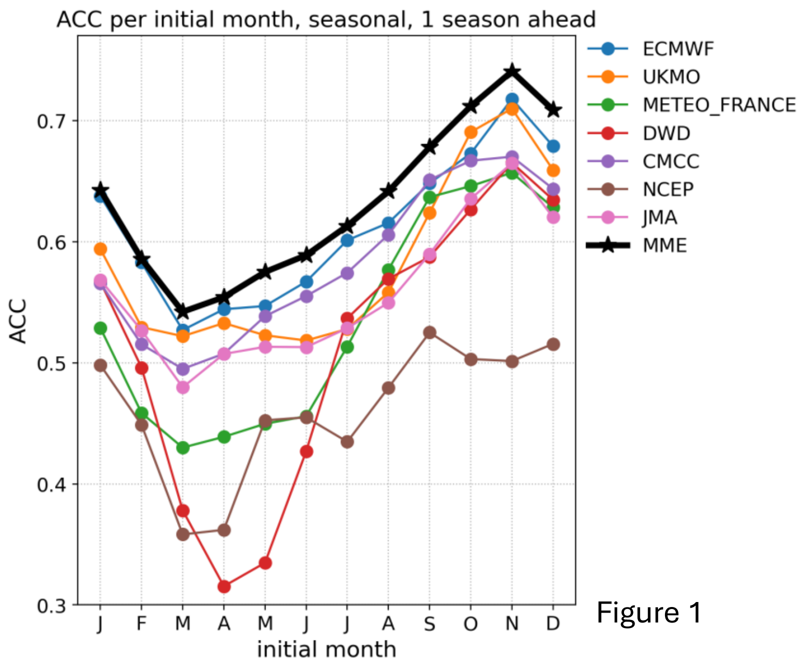



Figure 1

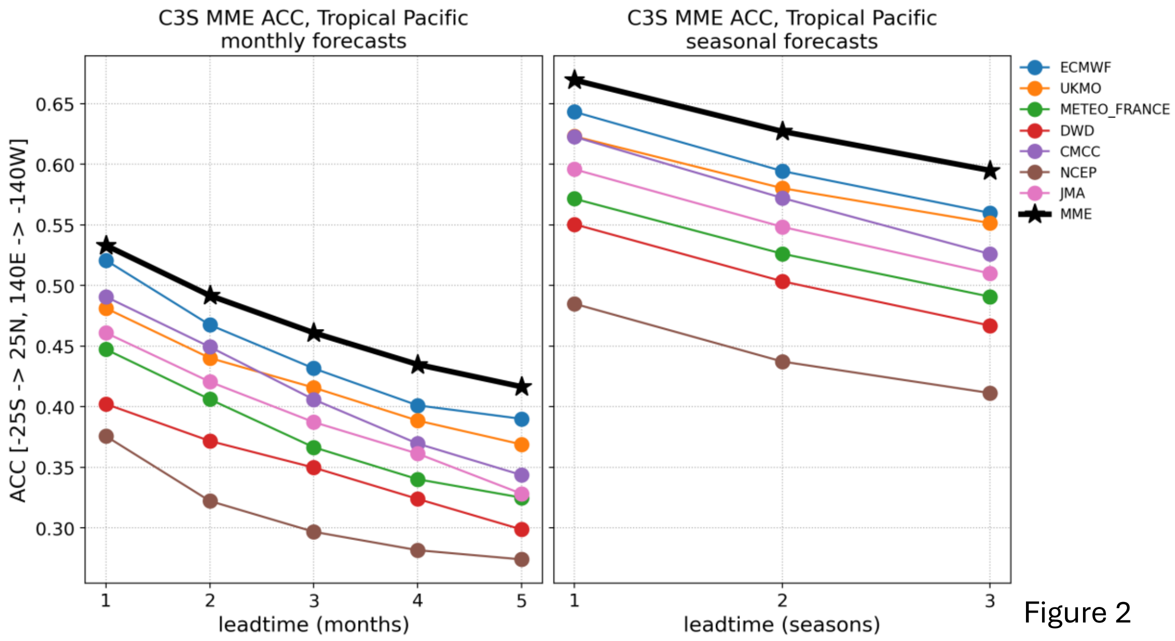
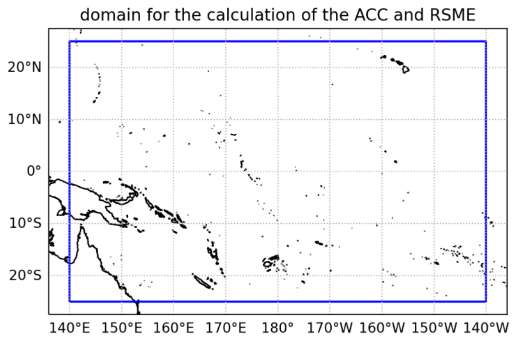



Figure 2




- ICU forecasts of rainfall are derived using a “multi-model ensemble” (black line, Figure 1 & 2)
- The average of the ensemble outperforms even the best ensemble member (coloured lines)
- Seasonal (three-month) forecasts issued in November have the highest skill (Figure 1)
- Seasonal forecasts issued between July-January are the most skillful (ACC > 0.6) (Figure 1)
- Seasonal forecasts issued between February-June have lower skill (ACC < 0.6) (Figure 1)
- Seasonal forecasts have higher skill than monthly forecasts (Figure 2)

# Long-term verification metrics & El Niño/La Niña

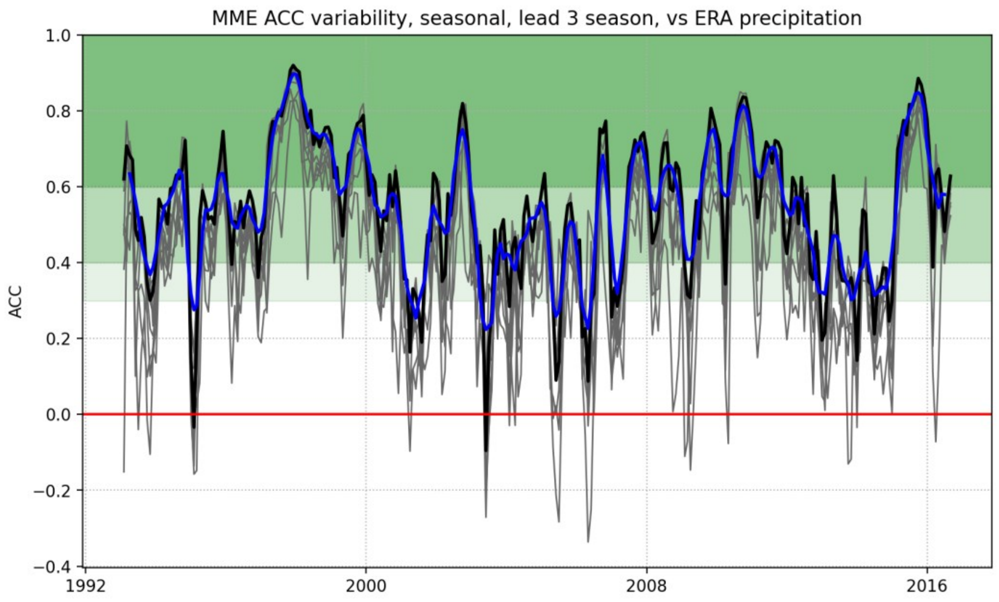



Figure 3

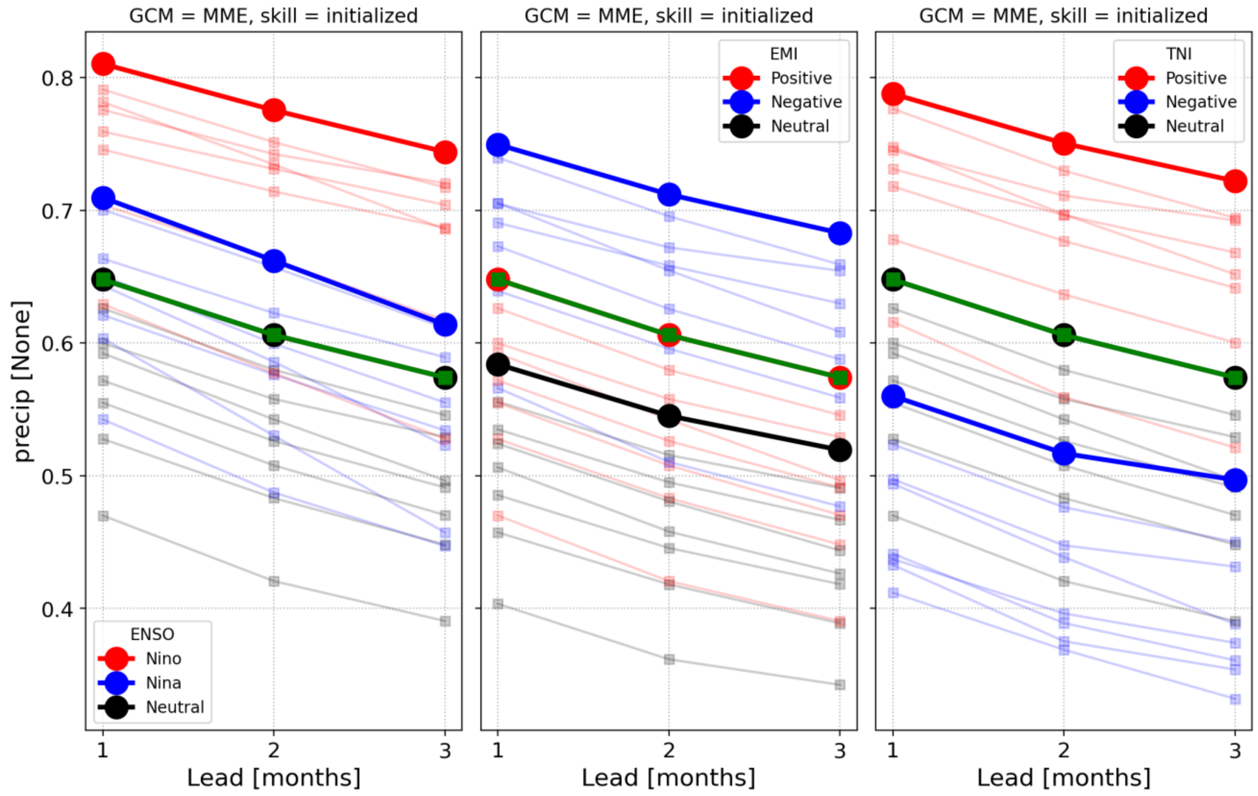



Figure 4

- Forecast skill for rainfall is highest during El Niño & second highest during La Niña (Figure 4, panel 1)
- During central Pacific ENSO events (so-called Modoki), forecast skill is highest during La Niña (Figure 4, panel 2)
- When the eastern equatorial Pacific is much warmer than the west, forecast skill is highest (Figure 4, panel 3)
- Historically speaking, forecast skill peaked during the El Niño of 1997-98 and 2015-16 (Figure 3)

# El Niño/La Niña verification metrics (cont'd)

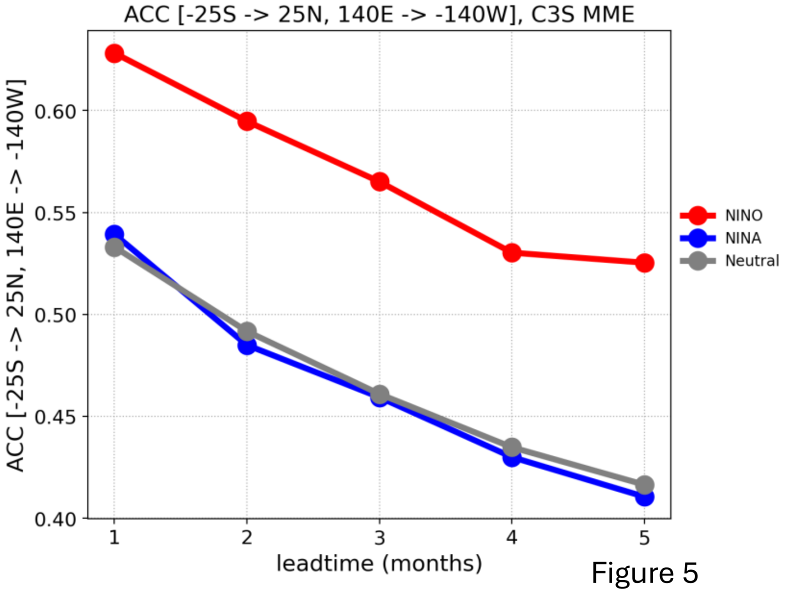



Figure 5

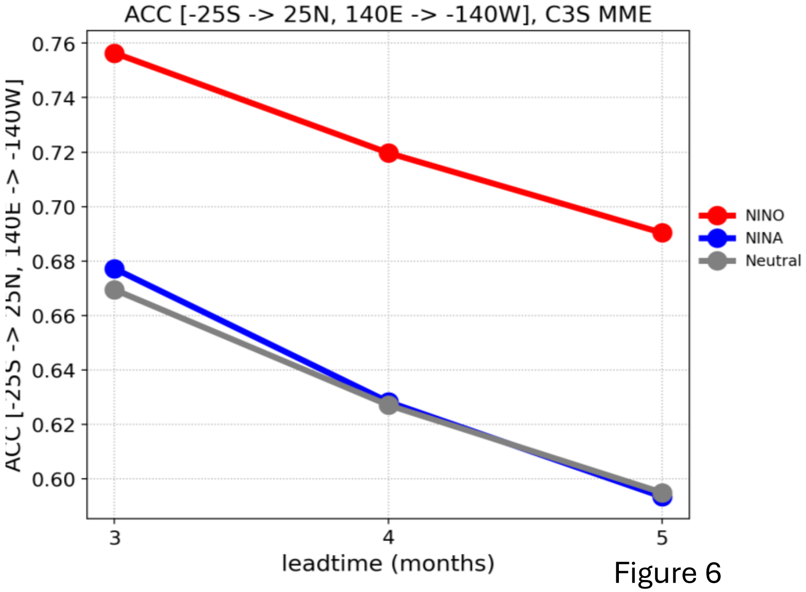



Figure 6

- Like the previous plots, these plots demonstrate that both monthly and seasonal forecast skill is highest in the Pacific during El Niño events

# Verification maps across the Pacific Islands

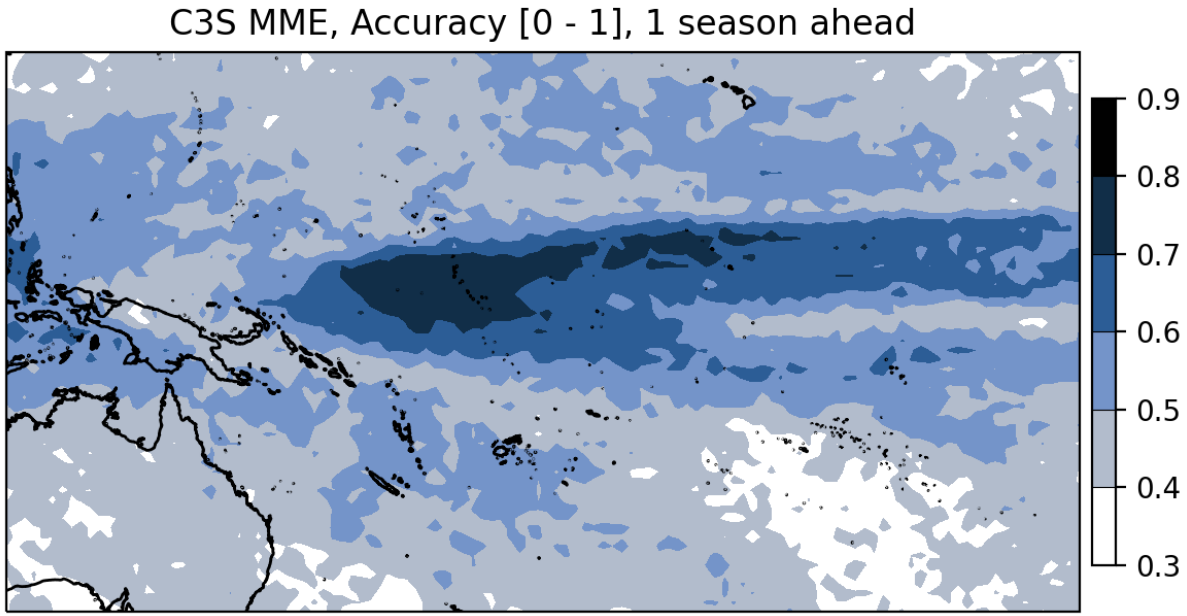



Figure 7

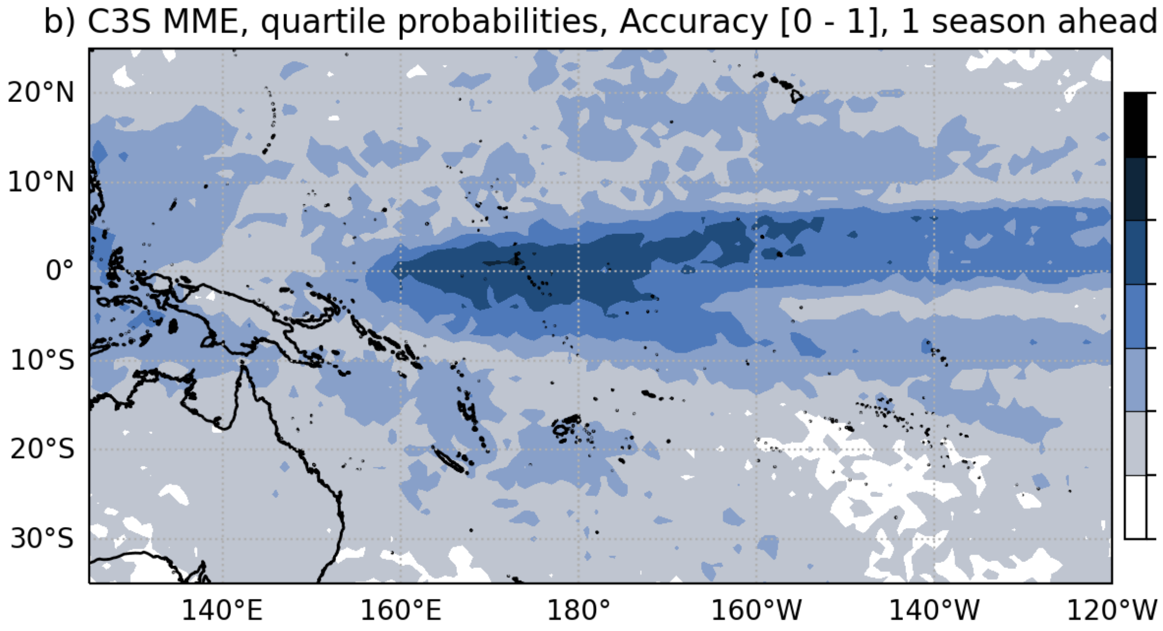



Figure 8

- Tercile (Figure 7) and quartile (Figure 8) forecast skill is highest near the equator
- Forecast skill is moderate across much of Micronesia and Melanesia
- Forecast skill is lower across south-east Polynesia

# Forecast skill during droughts

- These skill metrics examine the number of predictions of very low rainfall that turn out to be correct, providing insight on how accurate forecasts of meteorological drought are
- Overall, forecasts of dryness and drought near the equator are the most skillful, but skill across several island groups in Micronesia and Melanesia are good
- Drought predictions have low skill across south-east Polynesia

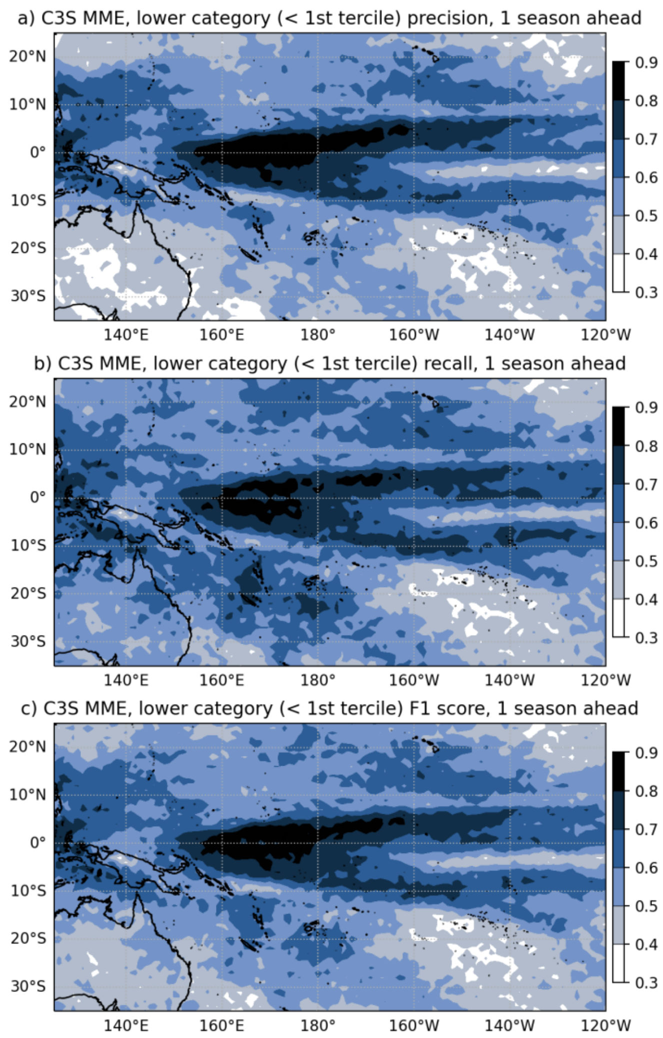



Figure 9

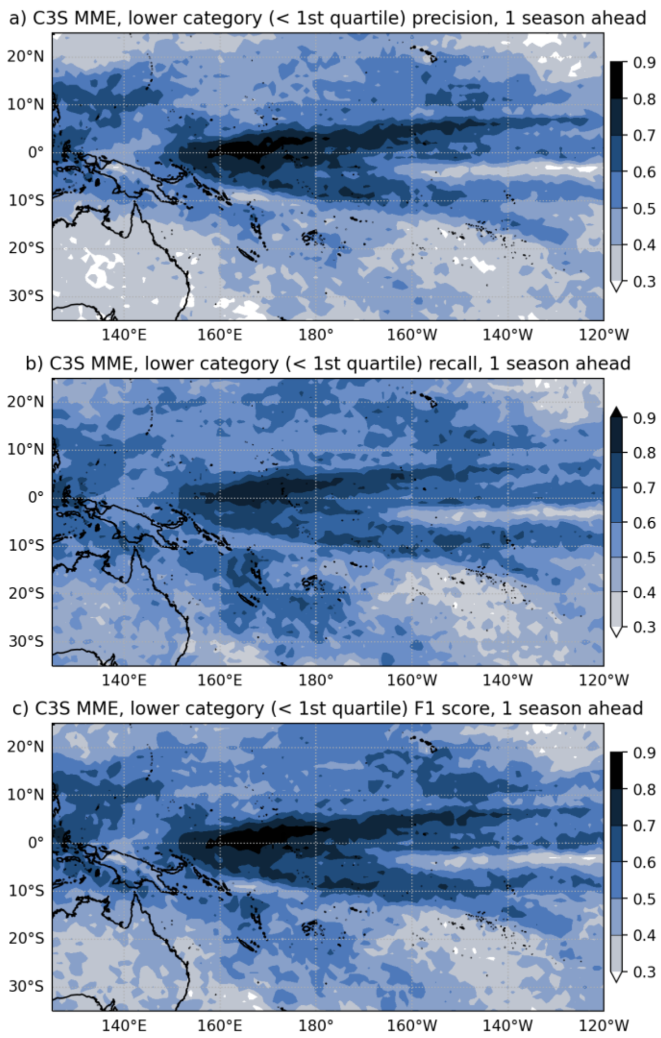
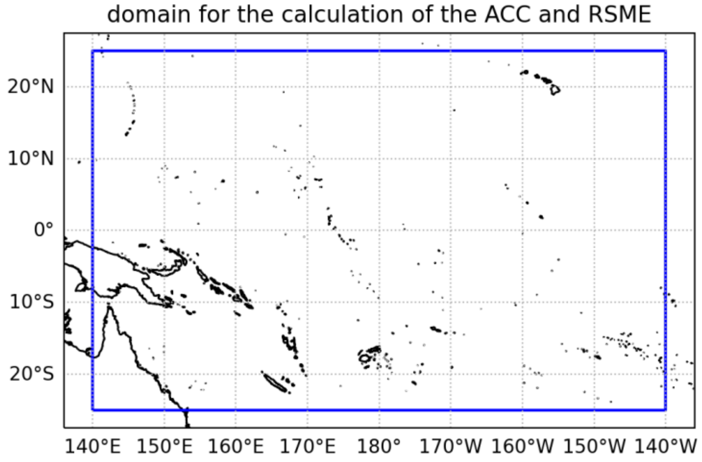



Figure 10

# Forecast skill heatmap during months & seasons



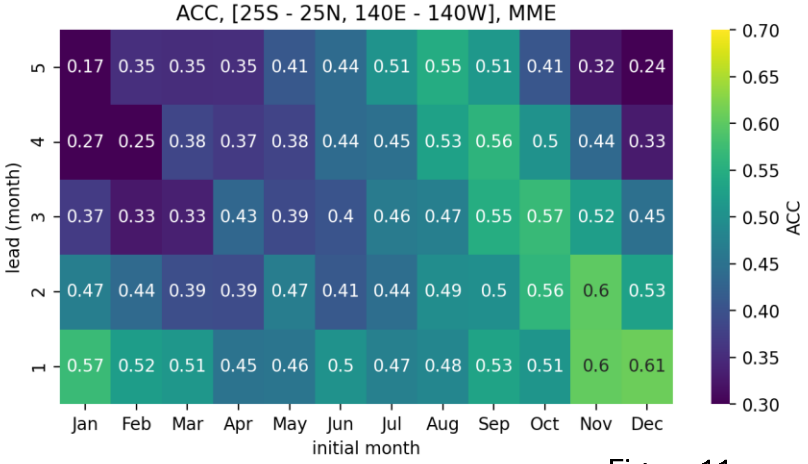




Figure 11

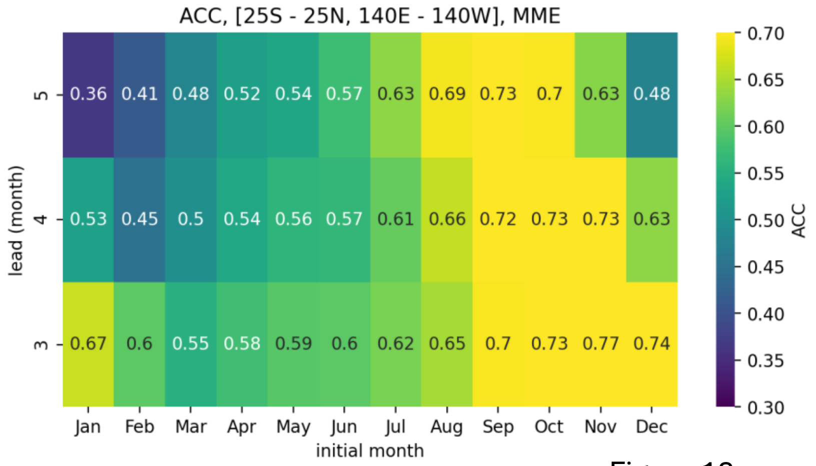



Figure 12

- Monthly forecast skill across the region (Figure 11) is typically highest for forecasts made between August-December and lowest between February-July, consistent with the typical peak effect of El Niño & La Niña events

- Seasonal forecast skill (Figure 12) is highest for forecasts made from July through December, again consistent with the typical development and peak of the ENSO cycle

# Forecast skill for different countries & districts

| Country | District | 3 | 4 | 5 |
|---|---|---|---|---|
| Kiribati | Gilberts-South | 78% | 74% | 69% |
| Kiribati | Gilberts-North | 75% | 72% | 72% |
| Nauru | Nauru | 75% | 69% | 63% |
| Kiribati | Ocean Island | 74% | 68% | 64% |
| Kiribati | Northern Line Islands | 71% | 69% | 70% |
| Kiribati | Phoenix Islands | 66% | 63% | 60% |
| Tuvalu | Northern Tuvalu | 66% | 63% | 63% |
| French Polynesia | Marquesas Islands | 61% | 55% | 56% |
| Kiribati | Southern Line Islands | 59% | 57% | 55% |
| Vanuatu | Torba | 59% | 56% | 53% |
| Tokelau | Tokelau | 59% | 55% | 52% |
| Cook Islands | Northern Cook Islands | 58% | 56% | 56% |
| Tuvalu | Southern Tuvalu | 58% | 55% | 55% |
| Palau | Babeldaob region | 57% | 57% | 51% |
| Palau | South-west Islands | 57% | 50% | 43% |
| FSM | Kapingamarangi | 57% | 54% | 49% |
| Vanuatu | Penama | 55% | 55% | 57% |
| Papua New Guinea | Southern Region | 55% | 53% | 50% |
| Fiji | Western | 54% | 54% | 53% |
| Vanuatu | Sanma | 54% | 57% | 53% |
| FSM | Pohnpei | 54% | 54% | 54% |
| New Caledonia | Loyalty Islands Province | 54% | 55% | 54% |
| FSM | Yap | 54% | 55% | 48% |
| Papua New Guinea | Highlands Region | 53% | 46% | 47% |
| Tonga | Vavau | 53% | 53% | 49% |
| Vanuatu | Tafea | 53% | 55% | 53% |
| Marshall Islands | Southern Marshall Islands | 53% | 52% | 47% |
| Fiji | Central | 53% | 51% | 49% |
| Vanuatu | Shefa | 53% | 54% | 52% |
| Vanuatu | Malampa | 52% | 51% | 52% |
| New Caledonia | South Province | 52% | 49% | 51% |
| Fiji | Eastern | 52% | 54% | 51% |
| Papua New Guinea | Momase Region | 52% | 46% | 45% |
| Solomon Islands | Choiseul Province | 51% | 48% | 47% |
| New Caledonia | North Province | 51% | 47% | 47% |
| American Samoa | Swains | 51% | 48% | 48% |
| Tonga | Haapai | 51% | 52% | 52% |
| FSM | Chuuk | 51% | 51% | 49% |
| Solomon Islands | Temotu Province | 50% | 50% | 42% |
| FSM | Kosrae | 50% | 49% | 48% |
| Guam | Guam | 50% | 47% | 51% |
| Northern Mariana Islands | Northern Islands | 49% | 41% | 40% |
| Solomon Islands | Isabel Province | 49% | 50% | 45% |
| Niue | Niue | 49% | 48% | 49% |
| Papua New Guinea | Islands Region | 49% | 45% | 46% |
| Northern Mariana Islands | Southern Islands | 49% | 45% | 46% |
| Solomon Islands | Makira-Ulawa Province | 48% | 46% | 44% |
| Tonga | Tongatapu-Eua | 48% | 48% | 49% |
| Kiribati | Central Line Islands | 48% | 46% | 43% |
| Fiji | Northern | 47% | 47% | 45% |
| Solomon Islands | Rennell and Bellona | 47% | 45% | 45% |
| American Samoa | Manua | 47% | 43% | 42% |
| Marshall Islands | Northern Marshall Islands | 46% | 43% | 40% |
| Marshall Islands | Central Marshall Islands | 46% | 42% | 42% |
| Samoa | Savaii | 46% | 44% | 43% |
| Solomon Islands | Central Province | 46% | 44% | 42% |
| Fiji | Rotuma | 46% | 45% | 46% |
| Tonga | Niuas | 46% | 46% | 46% |
| American Samoa | Tutuila | 46% | 44% | 42% |
| French Polynesia | Tuamotu Archipelago | 45% | 48% | 43% |
| Solomon Islands | Malaita Province | 45% | 43% | 41% |
| Samoa | Upola | 45% | 43% | 40% |
| Pitcairn | Ducie | 45% | 41% | 43% |
| Solomon Islands | Wesgtern Province | 44% | 44% | 43% |
| Solomon Islands | Guadacanal Province | 44% | 41% | 41% |
| Pitcairn | Pitcairn, Henderson & Oeno | 44% | 38% | 40% |
| Wallis et Futuna | Futuna | 43% | 46% | 47% |
| Wallis et Futuna | Wallis | 41% | 42% | 42% |
| French Polynesia | Austral Islands | 40% | 37% | 37% |
| French Polynesia | Gambier Islands | 39% | 31% | 38% |
| Cook Islands | Southern Cook Islands | 38% | 41% | 37% |
| French Polynesia | Windward-Society Islands | 38% | 35% | 32% |
| French Polynesia | Leeward-Society Islands | 33% | 32% | 33% |

- These tables show accuracy (hit) rates for tercile seasonal forecasts ending three months, four months, and five months ahead
- Accuracy of at least 40% is shaded in green
- For tercile probabilistic forecasts, a climatological forecast would have an accuracy of 33%

# Key messages about C3S MME skill

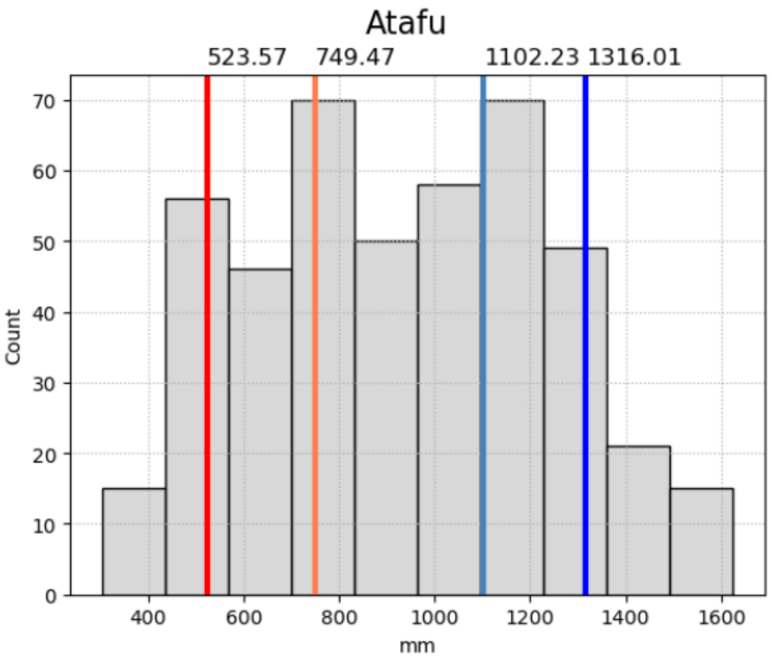
- The average of the multi-model ensemble forecast always outperforms the forecast from best ensemble member on a monthly and seasonal scale.
- Seasonal (three-month) forecasts issued between July-January tend to be the most skillful.
- One-month forecasts made between September-January tend to be the most skillful.
- Seasonal forecasts issued between February-June tend to have lower skill, but for most island groups, having a forecast is still much better than not having one at all.
- Forecast skill is highest for island groups nearest the equator, with moderate skill across Micronesia and Melanesia. Skill is lower across south-east Polynesia.
- The C3S MME can make skilful forecasts of the potential for meteorological drought
- Forecasts made during El Niño events typically have higher skill than ones made during La Niña or in neutral conditions.

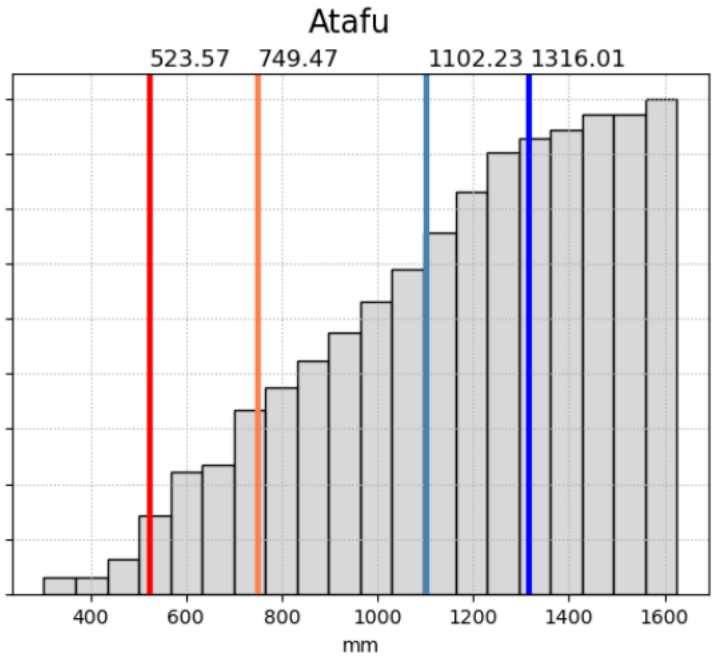
# Terciles !

Example for **Atafu**, taking data from MSWEP (Multi-Scale Weighted Ensemble Precipitation)

**90 days accumulations** (total rainfall) ending on the 1st of April

All data over the climatological period (**1991 – 2020, 30 years**), but 7 days each side of April 1st : 30 X 15 = **450 values**




150 out of 450 (33%) values are BELOW 750 mm

150 out of 450 (33%) values are ABOVE 1102 mm

45 out of 450 (10%) values are BELOW 523 mm

45 out of 450 (10%) values are ABOVE 1316 mm

750 mm: Value for the **1st tercile** if below = "**Below normal**" category
1102 mm: Value for the **2nd tercile** if Above = "**Above normal**" category

# Terciles !

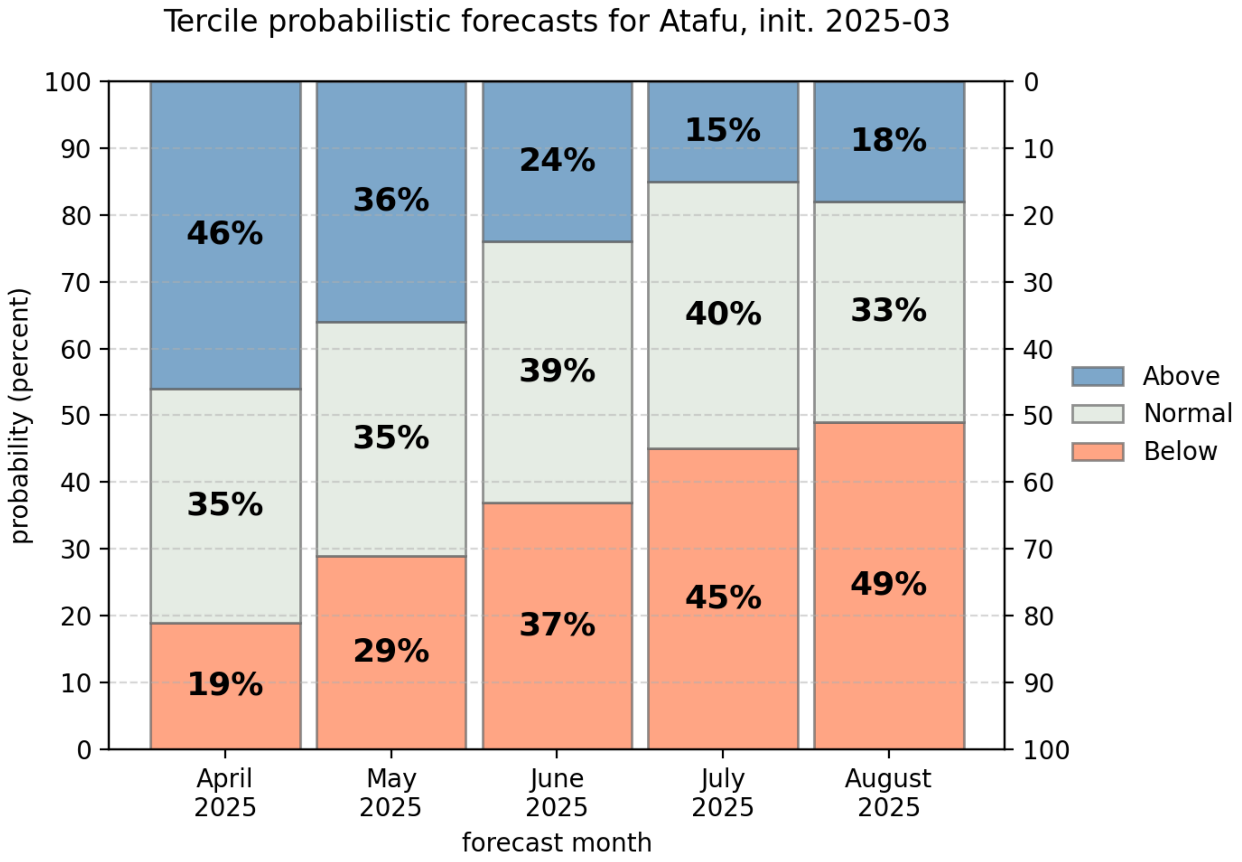
**Example: How are the tercile probabilities for Atafu calculated ?**

https://nicolasfauchereau.github.io/Tokelau_NCOF/#monthly-terciles-probabilities

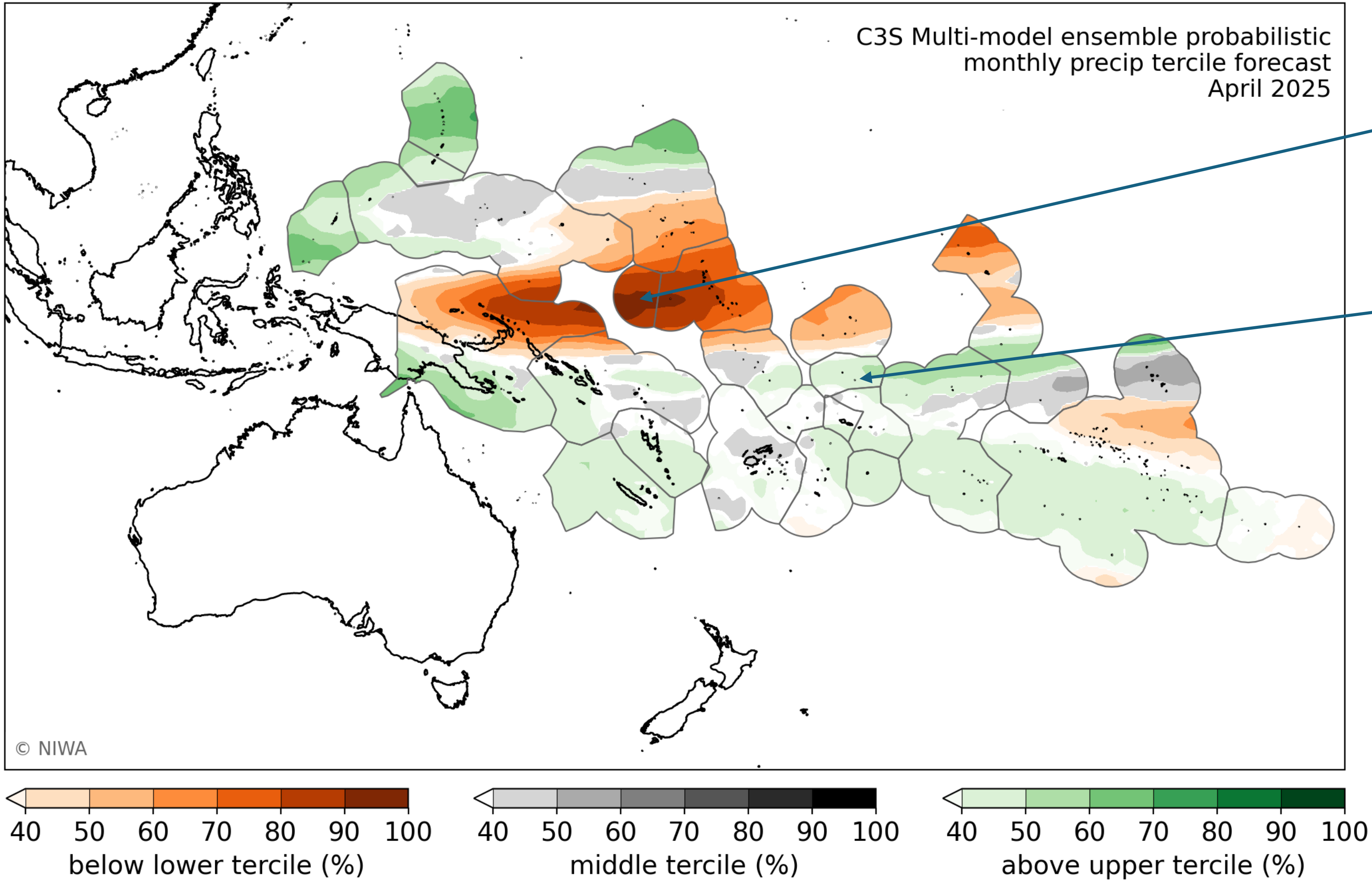
46% of the ensemble members (i.e. **230 out of 500**) fell above the climatological 66th percentile

The remaining members (**175**, i.e. **35 %**) fell in-between

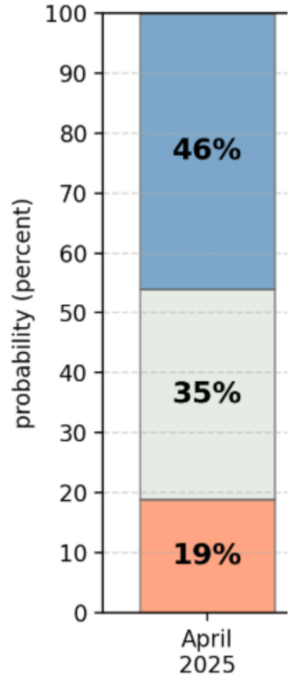
19% of the ensemble members (e.g, **95 out of 500**) fell below the climatological 33th percentile



Maps show the **MOST LIKELY CATEGORY**

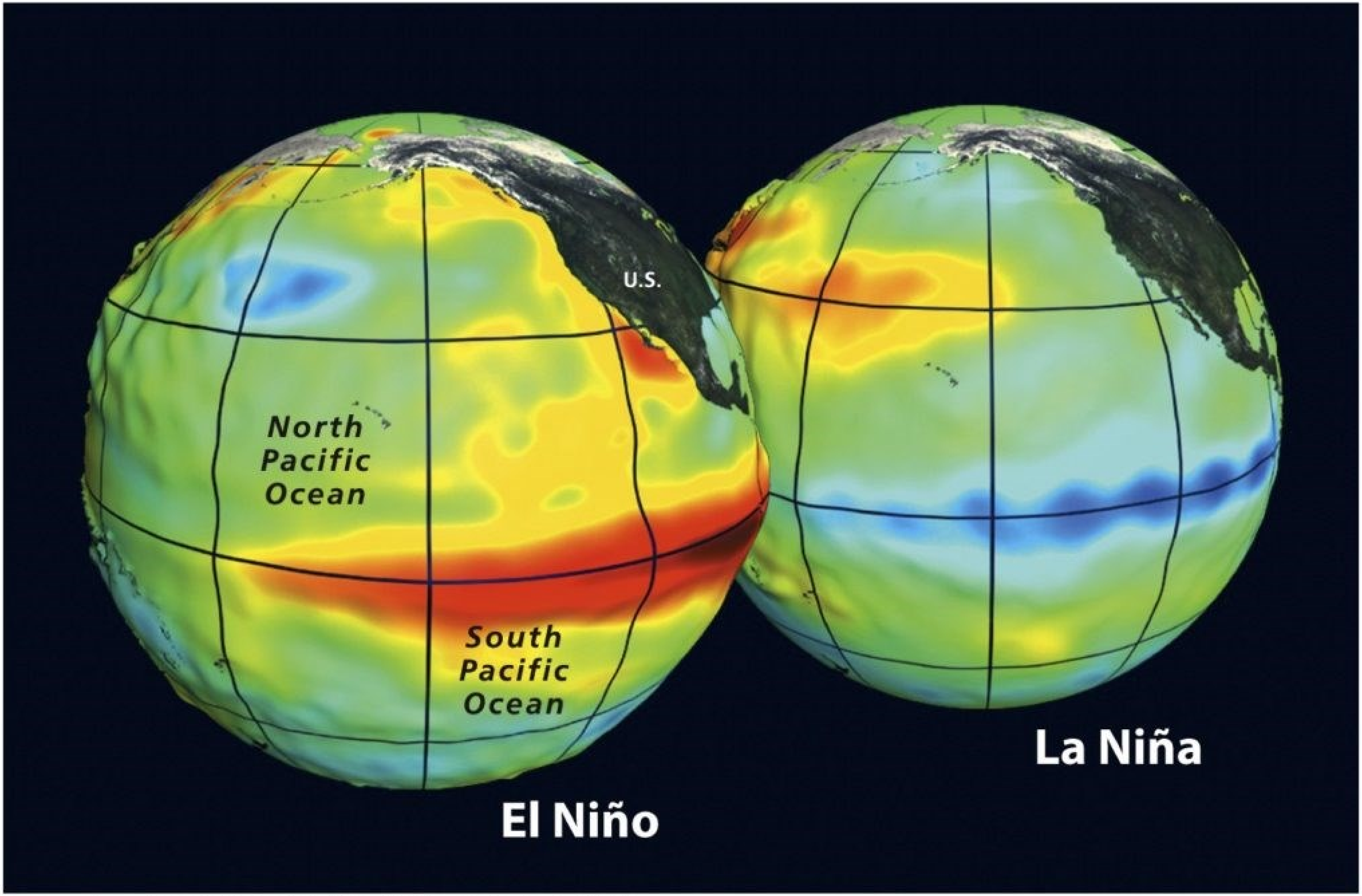



> 90% of the ensemble members (e.g, > **450 out of 500**) fell below the climatological 33th percentile




https://shiny.niwa.co.nz/icu-app/

# ENSO (El Nino – Southern Oscillation)



Courtesy Gregory W. Shirah, NASA/GSFC/Scientific Visualization Studio/NG Maps

# What is ENSO ?

**ENSO**, which stands for **El Niño-Southern Oscillation**, is a **naturally occurring phenomenon** involving **fluctuating ocean temperatures in the central and eastern equatorial Pacific, coupled with changes in the atmosphere**. It is considered the **strongest mode of coupled variability on an interannual timescale in the tropical Pacific**.
Here are the key aspects of ENSO:

• **Components**: ENSO has **oceanic** and **atmospheric components**.

  • **El Niño** refers to the **oceanic part**, characterized by **unusually warm waters** in the central and eastern tropical Pacific Ocean off the coast of Peru. The term "El Niño," meaning "boy child" or "Christ child" in Spanish, was originally used by fishermen in Peru and Ecuador to describe these warm waters that often appeared around December. This warming prevents cold, nutrient-rich waters from reaching the surface, affecting the fishing industry.

  • **La Niña** is the **opposite oceanic phase** of El Niño, characterized by **large-scale cooling of the ocean surface temperatures** in the same equatorial Pacific region. The name "La Niña" means "little girl".

  • The **Southern Oscillation** is the **atmospheric component**, which involves an **east-west see-saw-like movement of air masses** between the Pacific and the Indo-Australian areas, measured by changes in air pressure. During El Niño, abnormally high air pressure covers Indonesia, and abnormally low air pressure covers the central and/or eastern tropical Pacific (the **negative phase** of the Southern Oscillation). The reverse occurs during La Niña (the **positive phase**).

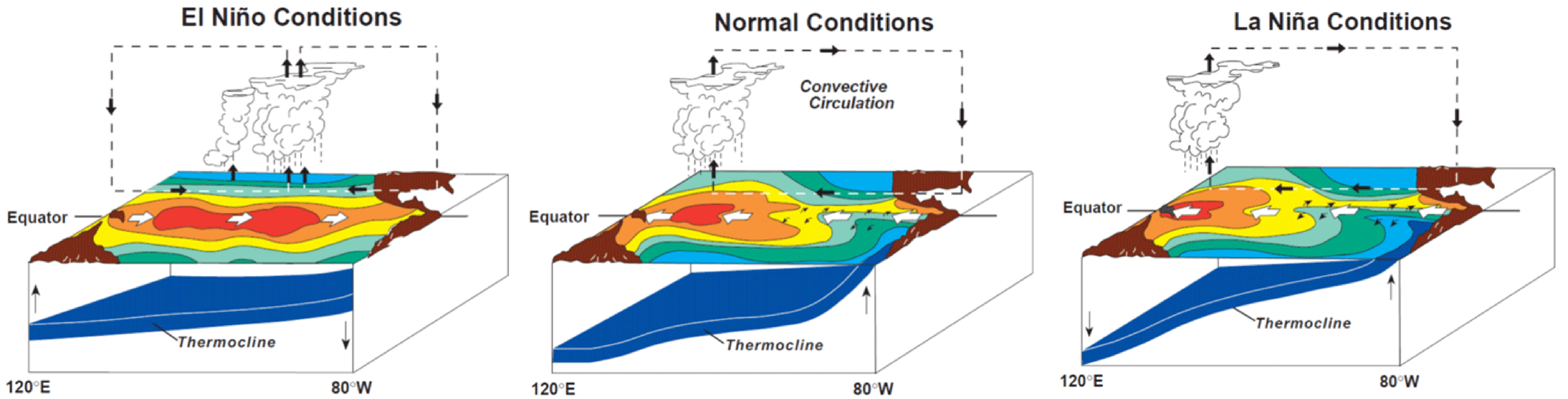
• **Ocean-Atmosphere Interaction**: El Niño and La Niña events begin with large-scale changes in ocean surface temperatures that then influence atmospheric circulation patterns. Conversely, these changes in atmospheric circulation also influence the ocean temperature patterns, creating a coupled system. For example, during El Niño, the typical east-to-west surface trade winds weaken or can even reverse, affecting the upwelling of cold water in the eastern Pacific and contributing to the warming.

• **Global Impacts (Teleconnections)**: The convection that form over the warm water during ENSO are intense enough to affect the global atmospheric circulation, altering the jet stream and influencing temperature and rainfall/snowfall patterns across the globe, particularly in the tropics.

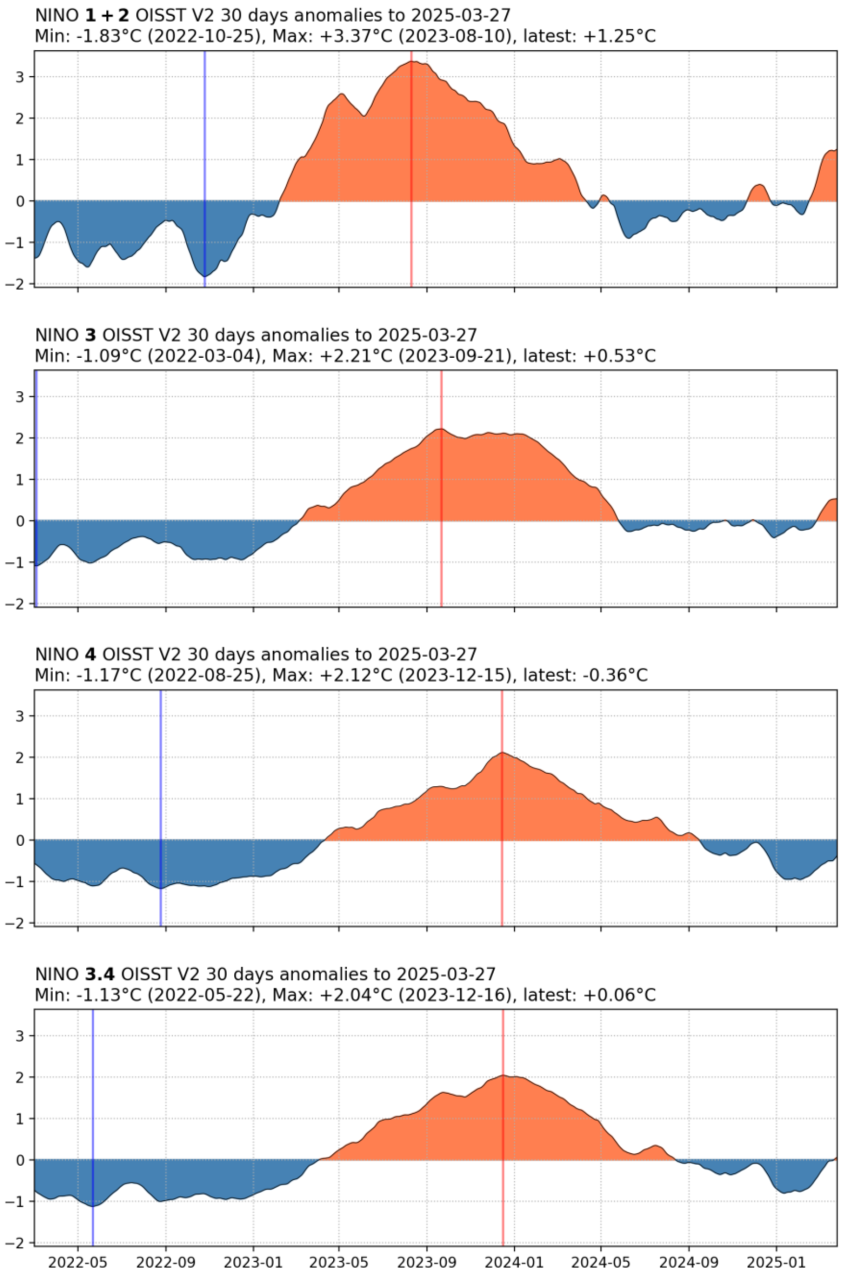
• **Predictability**: ENSO is considered the **most predictable season-to-season and year-to-year fluctuation of the climate system** due to the slow changes in ocean heat content preconditioning the system. Scientific progress has improved prediction skills within a range of one to nine months in advance. However, there is the known **"Spring Predictability Barrier" (SPB)**, which describes a **reduction in ENSO forecast skill for the May-June-July season**. This is because ENSO often decays in spring after its winter peak, sea surface temperature and sea level pressure anomalies are weakest, and the signal-to-noise ratio is small, making forecasts more sensitive to variability. The coupling between the ocean and atmosphere also weakens in spring.

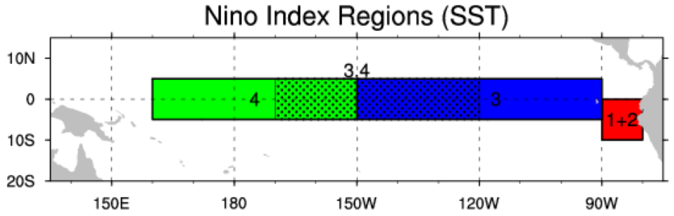
• **Socioeconomic Impacts**: ENSO events can have significant socioeconomic impacts, including affecting agriculture, water resources, energy demand, and the health sector (e.g., influencing the risk of certain diseases). Forecasting ENSO can help societies prepare for associated hazards like heavy rains, floods, and drought, potentially leading to significant economic savings.

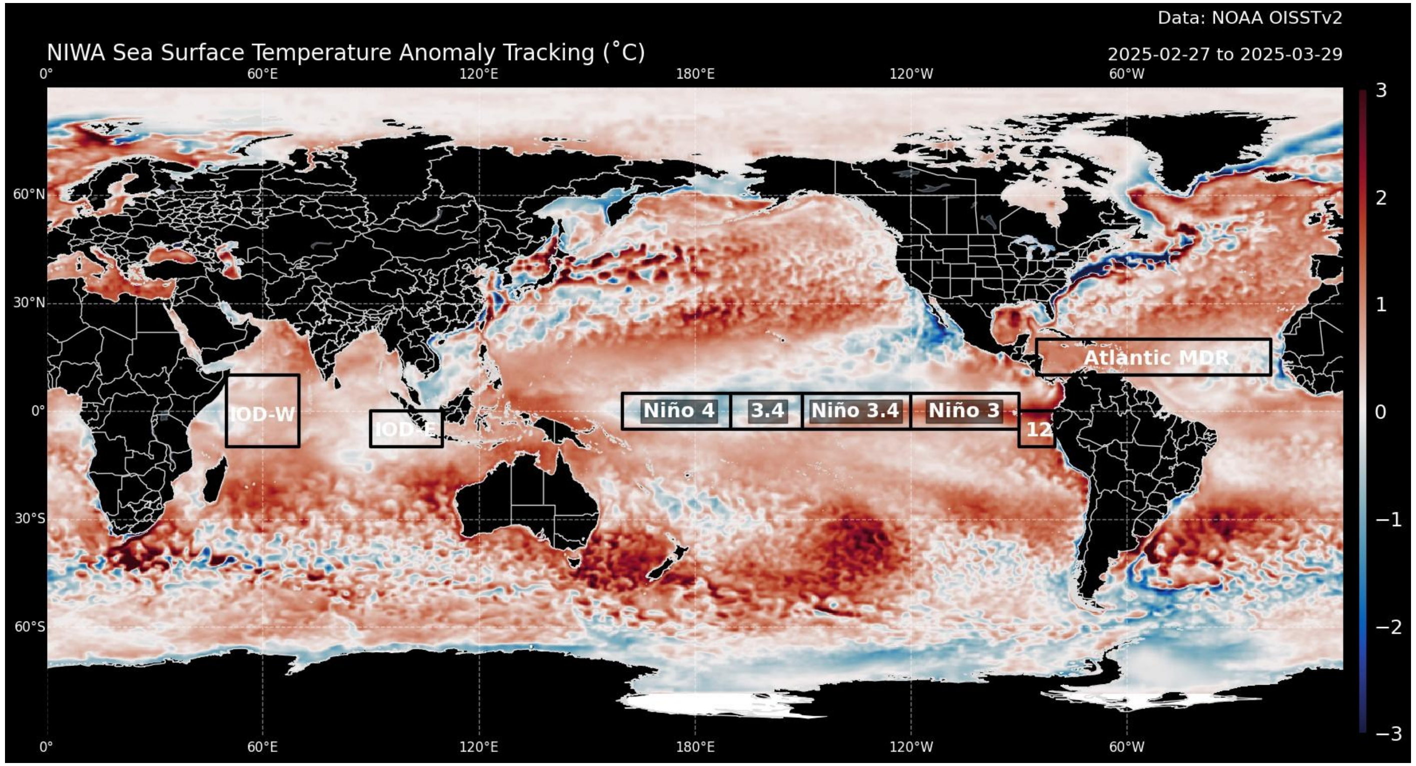
• **Monitoring and Prediction**: Meteorological and oceanographic data from observing systems like satellites and buoys are crucial for monitoring and forecasting El Niño and La Niña episodes. Dynamical and statistical forecast models are used to project the evolution of the tropical Pacific Ocean. The World Meteorological Organization (WMO) issues regular El Niño/La Niña Updates based on these observations and predictions, so is NIWA, the BoM, the APCC, etc


El Niño Conditions
Equator
Thermocline
120°E
80°W
Normal Conditions
Convective Circulation
Equator
Thermocline
120°E
80°W
La Niña Conditions
Equator
Thermocline
120°E
80°W

# Monitoring ENSO via SSTs in the Equatorial Pacific



# Monitoring ENSO (via SSTs) in a warming climate


Editorial Type: Meeting Summaries

Article Type: Meeting Report


Making Progress on the Operational Alerting of El Niño and La Niña in a Warming World


Matthew C. Wheeler, Hanh Nguyen, Chris Lucas, Zhi-Weng Chua, Simon Grainger, David A. Jones, Michelle L. L'Heureux, Ben Noll, Tristan Meyers, Nicolas C. Fauchereau, Alexandre Peltier, Thea Turkington, Hyung-Jin Kim, and Takafumi Umeda



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Page(s): E1042–E1044


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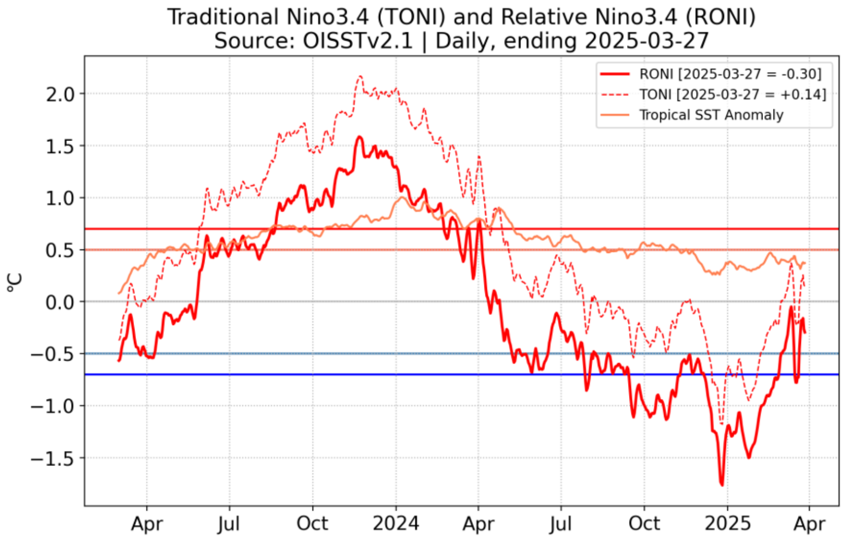
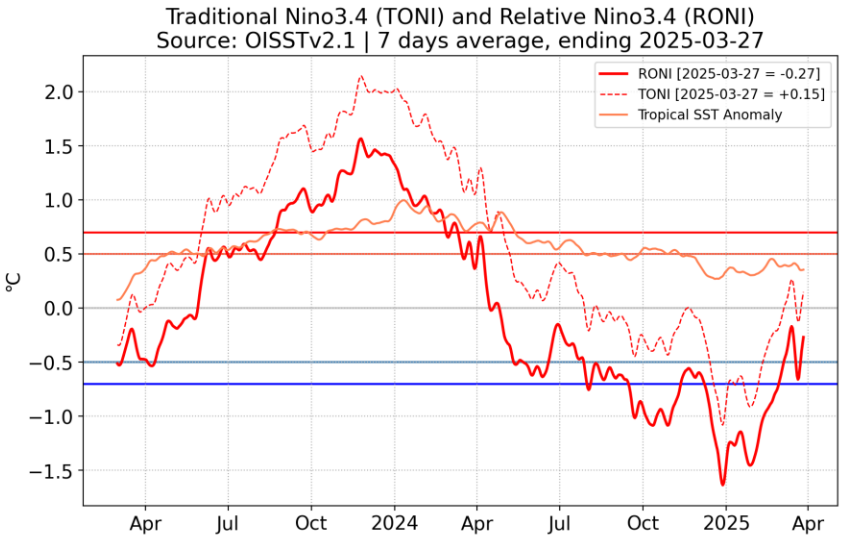
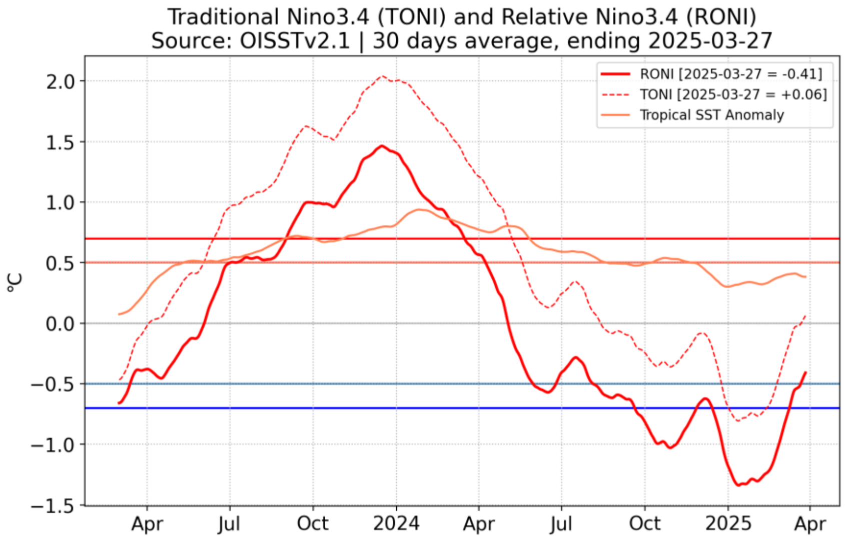
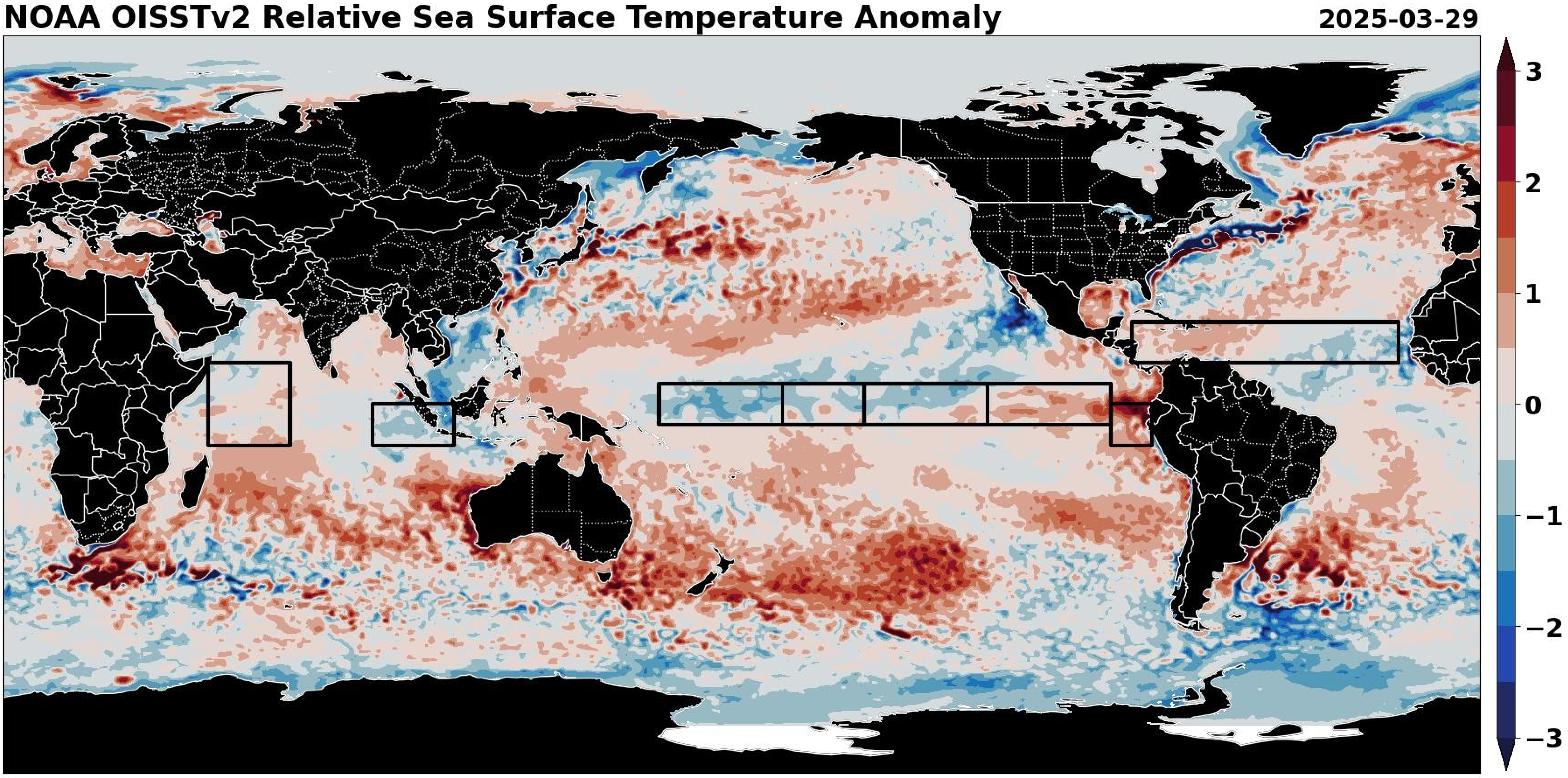


# Monitoring ENSO (via SSTs) in a warming climate



# The Pacific RCC ENSO tracker

**There is no on / off switch for El Nino and La Nina !**

Each event is different

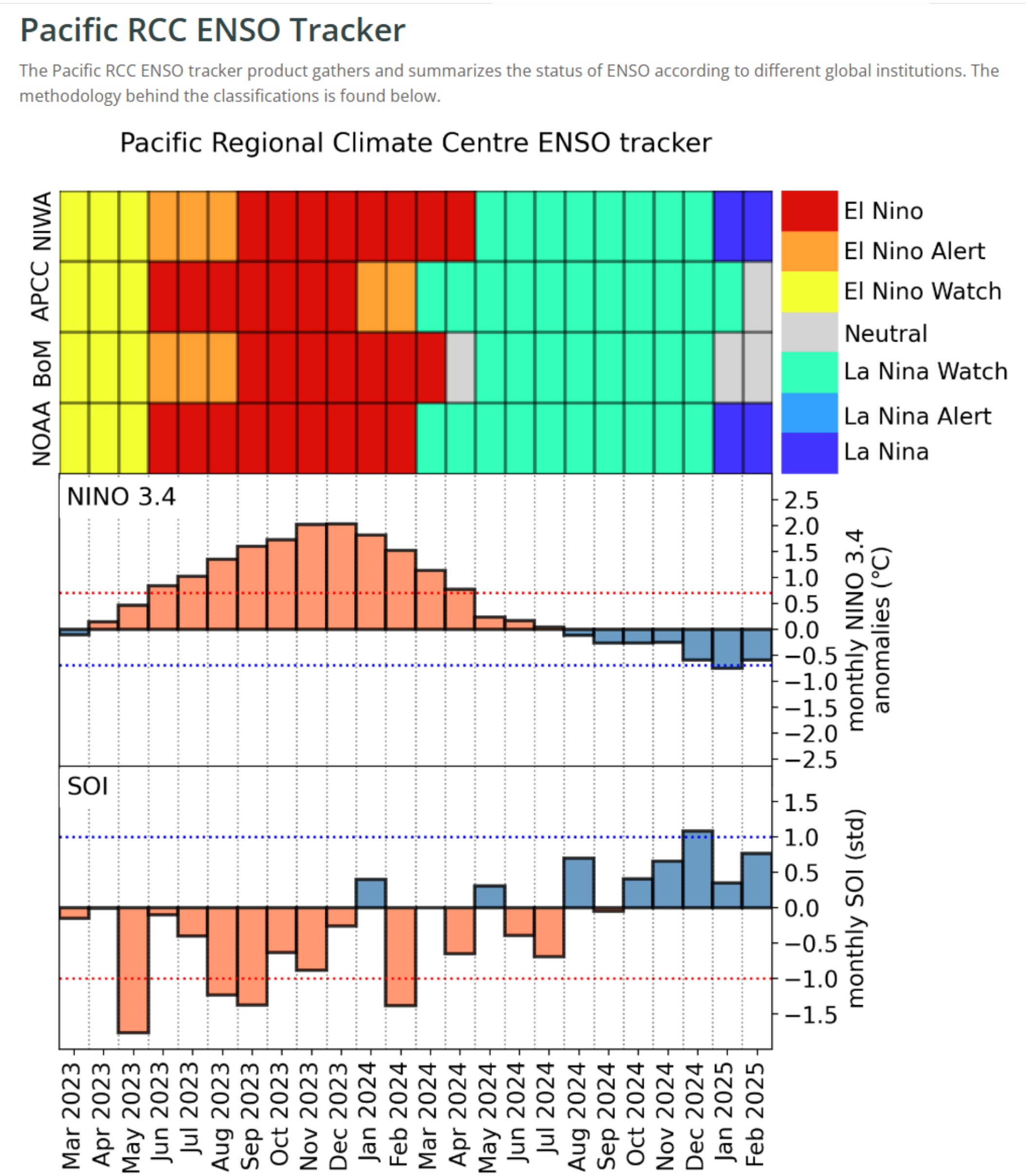
Different institutions use different criteria to 'declare' El Nino, La Nina, Neutral conditions

Some only look at SST (usually Nino 3.4 index), others also account for the Southern Oscillation Index

You can look at the different criteria at:

https://www.pacificmet.net/enso-tracker

The Pacific RCC maintains the 'ENSO tracker' which is updated every month (~ 5th of each month)



# Predictability of ENSO

The El Niño/Southern Oscillation is considered the **most predictable season-to-season and year-to-year fluctuation of the climate system.**

This is largely because **slow changes in ocean heat content precondition the system for warm (El Niño) and cold (La Niña) events to occur**. The ocean, with its large thermal inertia and relatively long dynamical timescales, varies more slowly than the atmosphere. These slowly evolving sea-surface temperature (SST) anomalies in the equatorial Pacific, which are central to ENSO, have a **characteristic persistence timescale**, making them a useful basis for prediction.

**Coupled ocean-atmosphere interactions and positive feedback:** ENSO is an **ocean–atmosphere coupled mode** in the tropical Pacific that evolves through **positive feedback between SST and trade winds**. Changes in SSTs affect atmospheric circulation (winds, pressure, and rainfall), which in turn can further influence the ocean, leading to a self-sustaining or amplifying cycle. This coupled nature, with its inherent time lags and feedbacks, provides a degree of predictability beyond that of the purely atmospheric variability.

**Characteristic evolution cycle:** ENSO events typically have a **distinct evolutionary cycle**, often beginning in the middle of the year, peaking during November-January, and then decaying in the first half of the following year. This relatively consistent temporal evolution aids in prediction as models and statistical methods can leverage this typical lifecycle.

**Observational monitoring systems:** The ability to monitor and forecast ENSO relies heavily on **meteorological and oceanographic data** drawn from various observing systems. These include **satellites** providing information on tropical rainfall, wind, and ocean temperatures, **buoys** measuring upper ocean and sea-surface temperatures, and **research ships and radiosondes** observing the atmosphere. Programmes like the Global Climate Observing System and the Global Ocean Observing System facilitate the exchange and processing of this crucial data . The Tropical Atmosphere Ocean (TAO) moored array across the equatorial Pacific, developed in the lead-up to and during the TOGA project, significantly improved ocean observations and contributed to the development of operational ENSO forecast systems.

The prediction of ENSO variability with a simple coupled ocean–atmosphere dynamical model was first demonstrated in the 1980s. Today's sophisticated operational ENSO forecast systems are based on these initial developments and have shown **noticeable improvement in predictive skill** over the last few decades due to advancements in estimating initial ocean and atmospheric conditions, model physics, and computing. These models can simulate the complex interactions between the ocean and atmosphere that drive ENSO.

**Identification of teleconnections:** The understanding that **ENSO has significant and generally opposite impacts on temperature and precipitation patterns across the globe** through **teleconnections** is crucial for its predictability. The identification of statistically significant ENSO-associated global climate teleconnections allows for ENSO-related parameters to be used as predictors in forecast models for large-scale climate anomalies in many countries. By understanding these remote influences, forecasts can extend beyond the immediate tropical Pacific region.

In summary, the seasonal to interannual predictability of ENSO arises from the **slow and coupled nature of the ocean-atmosphere system in the tropical Pacific**, which is effectively monitored by a global observing network and simulated by increasingly sophisticated dynamical models. The consistent evolution and far-reaching influence through teleconnections further enhance our ability to anticipate the onset, evolution, and impacts of El Niño and La Niña events.

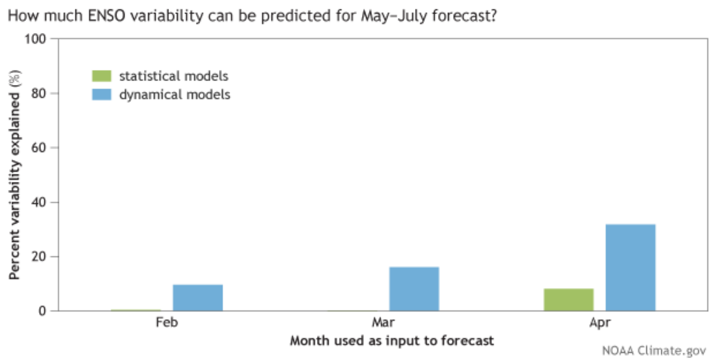
# But … there's the ENSO "spring" (our autumn !) predictability barrier

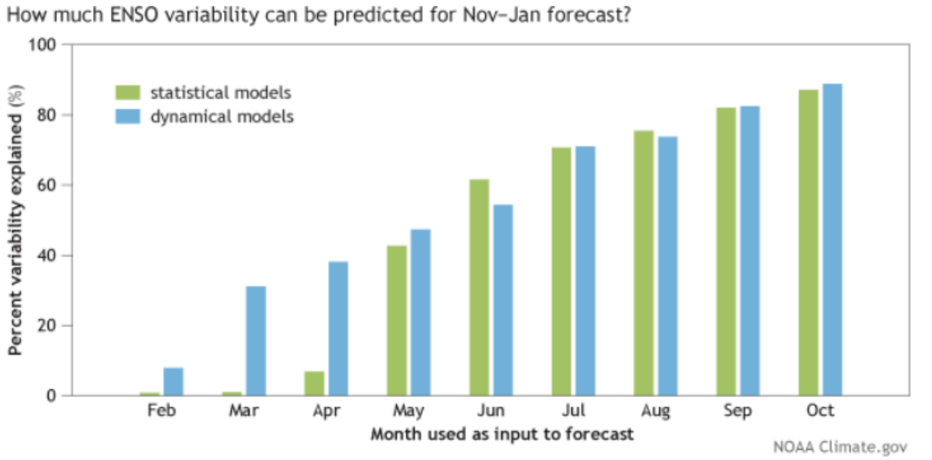
The **Spring Predictability Barrier (SPB)** is a well-known challenge in seasonal forecasting, specifically referring to a **reduction in ENSO forecast skill during the May-June-July season**. State-of-the-art forecasting models in February, March, and April experience a decrease in their ability to predict ENSO conditions for the subsequent spring (autumn in the Southern Hemisphere).

**Transitional Season:** Spring (our autumn) is a transitional period for ENSO after its typical winter peak. During this time, **sea surface temperature (SST) and sea level pressure anomalies, which are key indicators of ENSO, tend to be weakest**. However, the **noise (a measure of chaos) within the tropical Pacific air-sea system remains high**. This results in a **small signal-to-noise ratio in spring**, making forecasts more susceptible to variability and making it harder to determine the future phase of ENSO. This relates to the inherent limits of forecast skill discussed in the "guidance_seasonal_forecasting.pdf", where the non-linear nature of the climate system and errors in models contribute to these limitations. The degradation of predictability as forecast lead time increases, as illustrated in Figure 1.5, also becomes relevant during this transitional phase.

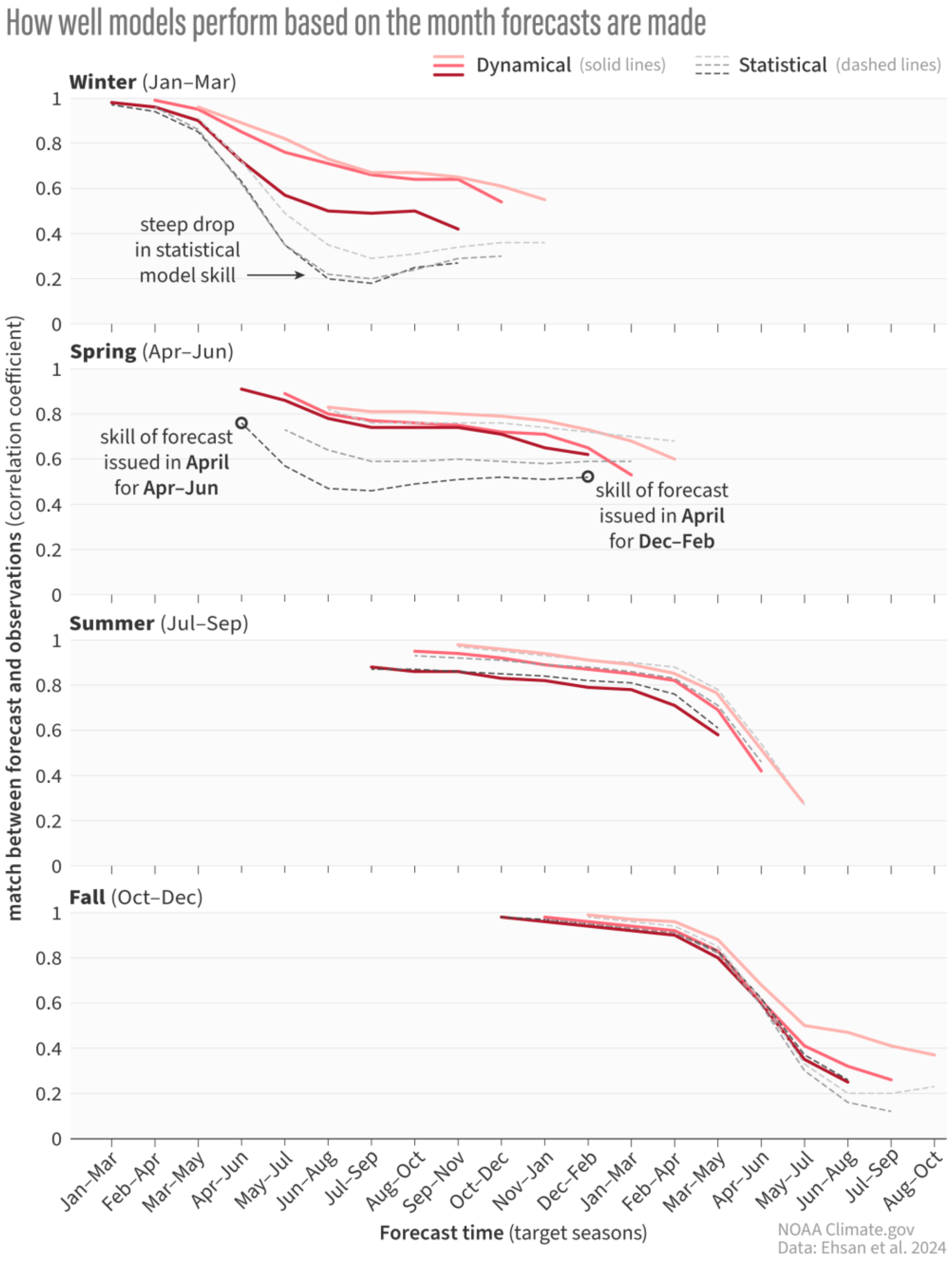
**Limitations in Data Gathering:** The future ocean state, particularly when El Niño is developing, heavily relies on initial ocean conditions. However, there are **limited observations of ocean temperature, especially below the surface**, leading models to potentially underrepresent the current state of the ocean. Errors in initial conditions, even small ones, can grow over time due to climate feedbacks.

https://www.climate.gov/news-features/blogs/enso/spring-predictability-barrier-we%E2%80%99d-rather-be-spring-break




The skill (or forecasting ability) of model runs based on February-October observations to predict the November-January (NDJ) average value in the Niño-3.4 SST region (ENSO). Results shown here are an average correlation coefficient from each of the 20 models between 2002-2011 (data used from Barnston et al, 2012). Percent Explained Variance (%) is calculated by squaring the correlation coefficient and multiplying by 100 (see footnote #1). Models that explain all ENSO variability would equal 100%, while explaining none of the ENSO variance would equal 0%. Graphic by Fiona Martin based on data from NOAA CPC and IRI.




[How good have models been at predicting ENSO in the 21st century? | NOAA Climate.gov]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Article | Open access | Published: 19 December 2024

# Real-time ENSO forecast skill evaluated over the last two decades, with focus on the onset of ENSO events


Muhammad Azhar Ehsan, Michelle L. L'Heureux, Michael K. Tippett, Andrew W. Robertson & Jeffrey Turmelle



npj Climate and Atmospheric Science 7, Article number: 301 (2024) | Cite this article





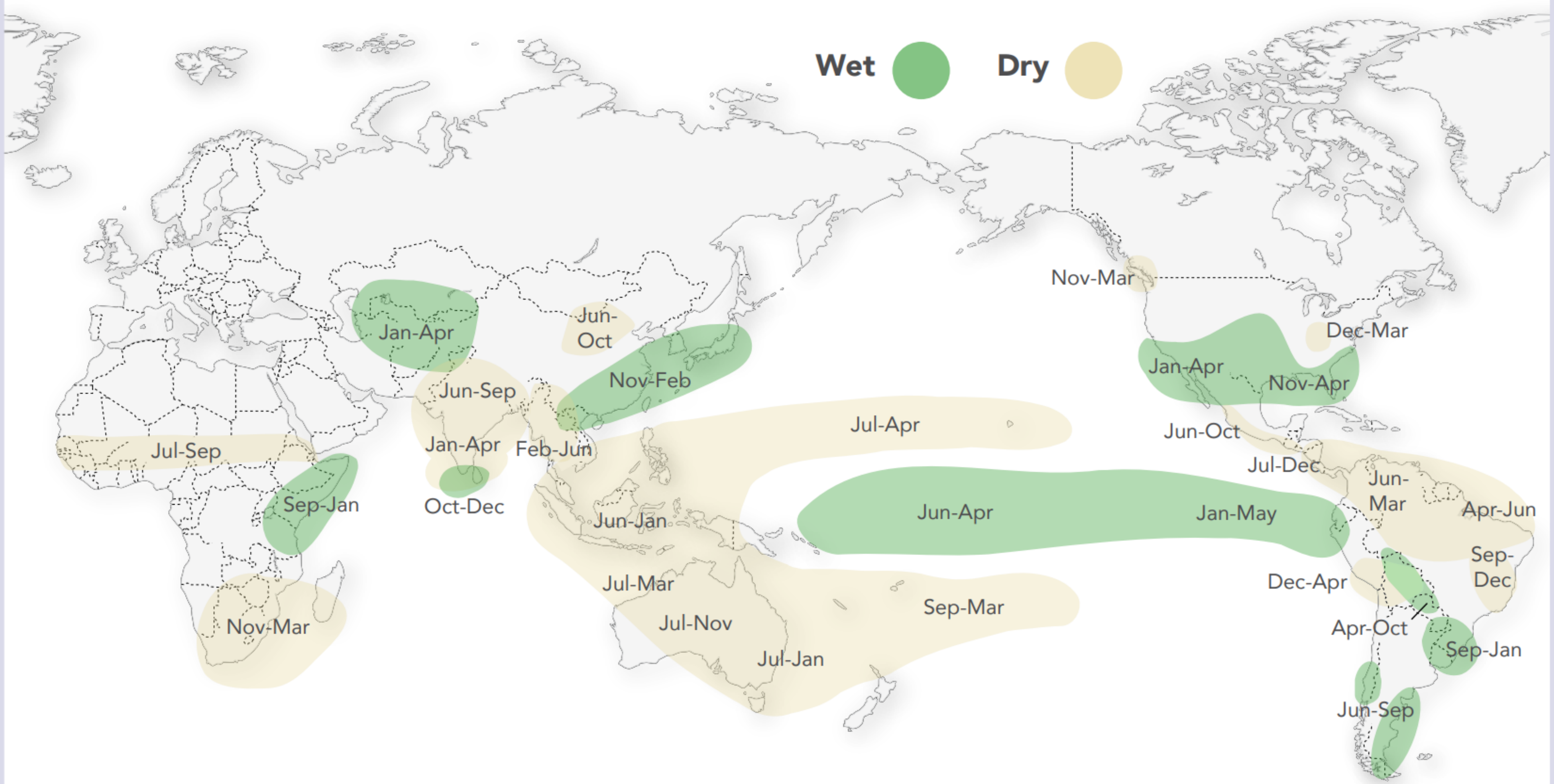
## Abstract

This paper provides an updated assessment of the "International Research Institute for Climate and Society's (IRI) El Niño Southern Oscillation (ENSO) Predictions Plume". We evaluate 253 real-time forecasts of the Niño 3.4 index issued from February 2002 to February 2023 and examine multimodal means of dynamical (DYN) and statistical (STAT) models separately. Forecast skill diminishes as lead time increases in both DYN and STAT forecasts, with peak accuracy occurring post-northern hemisphere spring predictability barrier and preceding seasons. The DYN forecasts outperform STAT forecasts with a pronounced advantage in forecasts initiated from late boreal winter through spring. The analysis uncovers an asymmetry in predicting the onset of cold and warm ENSO episodes, with warm episode onsets being better forecasted than cold onsets in both DYN and STAT models. The DYN forecasts are found to be valuable for predicting warm and cold ENSO episode onsets at least several months in advance, while STAT forecasts are less informative about ENSO phase transitions. The results indicate that predicting ENSO onset is challenging and that the ability to do so is both model- and event-dependent.

# ENSO impacts in the Pacific

# El Niño and Rainfall

El Niño conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. The regions and seasons shown on the map below indicate typical but not guaranteed impacts of La Niña. For further information, consult the probabilistic information* that the map is based on.




*http://iridl.ldeo.columbia.edu/expert/home/.lenssen/.ensoTeleconnections/
For more information on El Niño and La Niña: http://iri.columbia.edu/enso

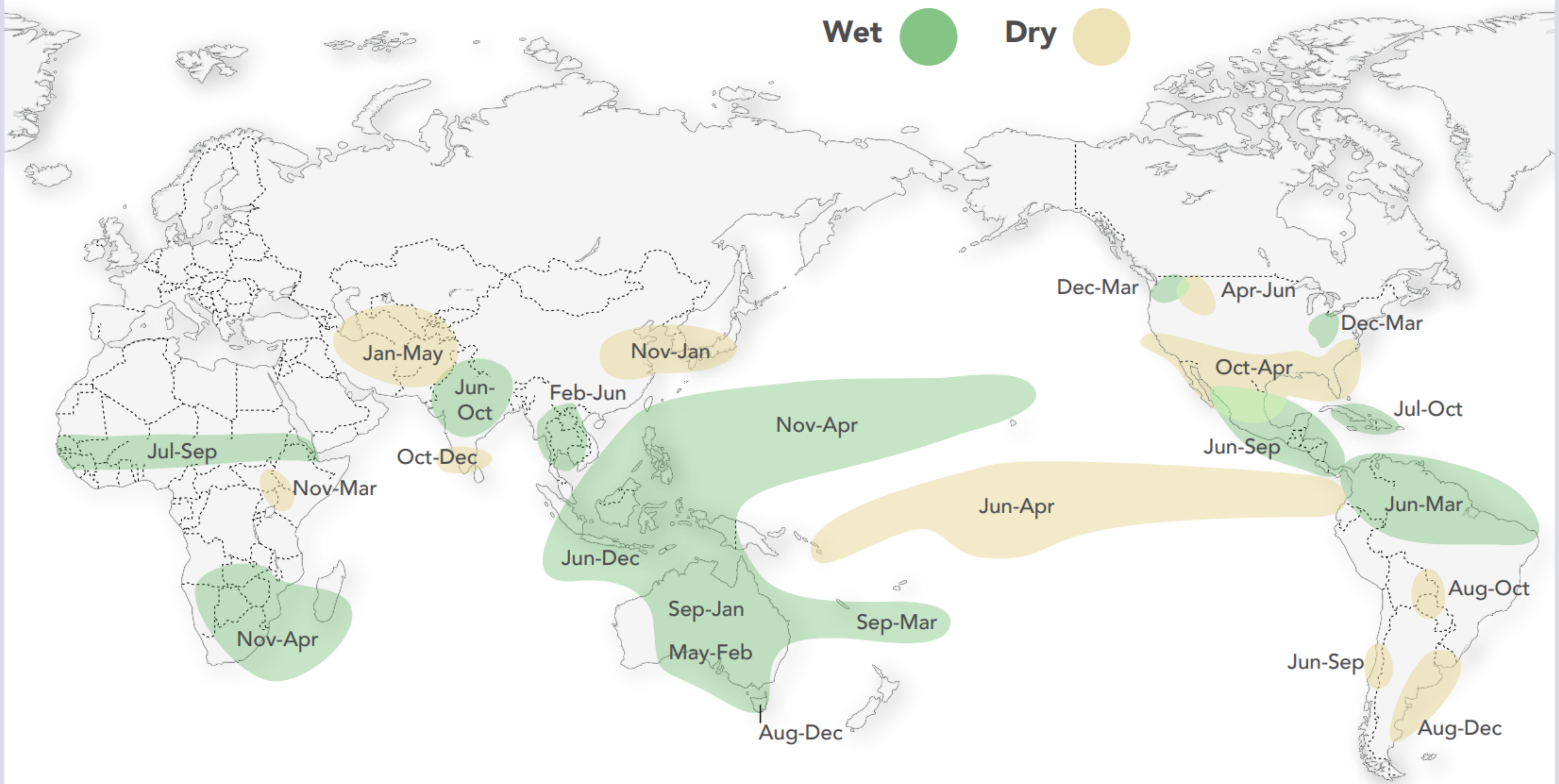

Sources:
1. Lenssen, Goddard and Mason, 2020. Seasonal Forecast Skill of ENSO Teleconnection Maps. Weather Forecasting, 2387–2406
2. Mason and Goddard, 2001. Probabilistic precipitation anomalies associated with ENSO. Bull. Am. Meteorol. Soc. 82, 619-638



International Research Institute for Climate and Society
Earth Institute | Columbia University

# La Niña and Rainfall

La Niña conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. The regions and seasons shown on the map below indicate typical but not guaranteed impacts of La Niña. For further information, consult the probabilistic information* that the map is based on.




*http://iridl.ldeo.columbia.edu/expert/home/.lenssen/.ensoTeleconnections/
For more information on El Niño and La Niña: http://iri.columbia.edu/enso

Sources:
1. Lenssen, Goddard and Mason, 2020. Seasonal Forecast Skill of ENSO Teleconnection Maps. Weather Forecasting, 2387–2406
2. Mason and Goddard, 2001. Probabilistic precipitation anomalies associated with ENSO. Bull. Am. Meteorol. Soc. 82, 619-638

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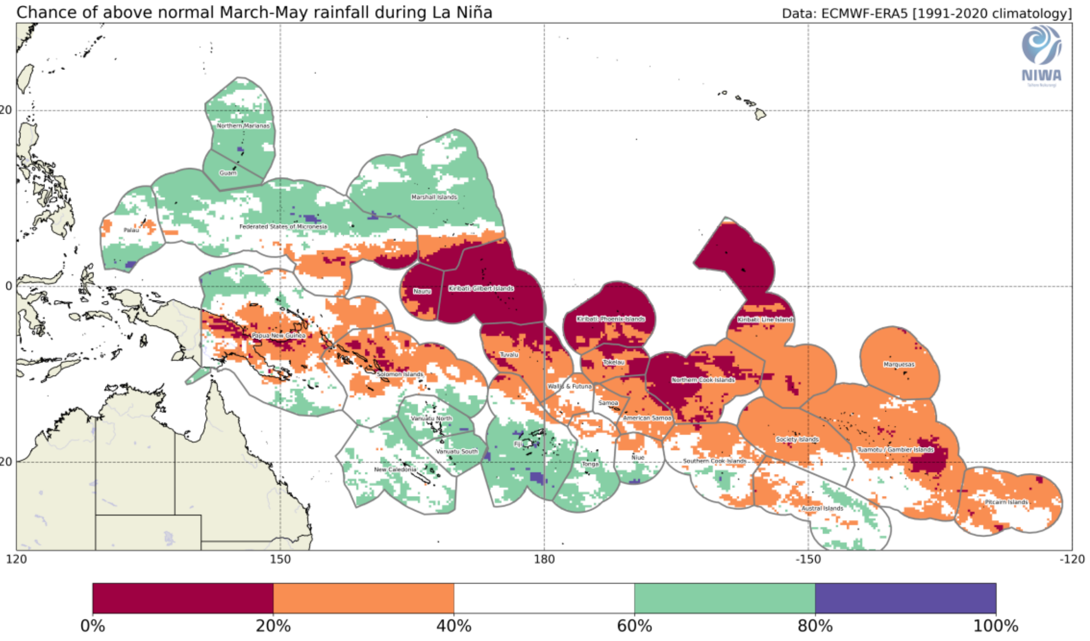
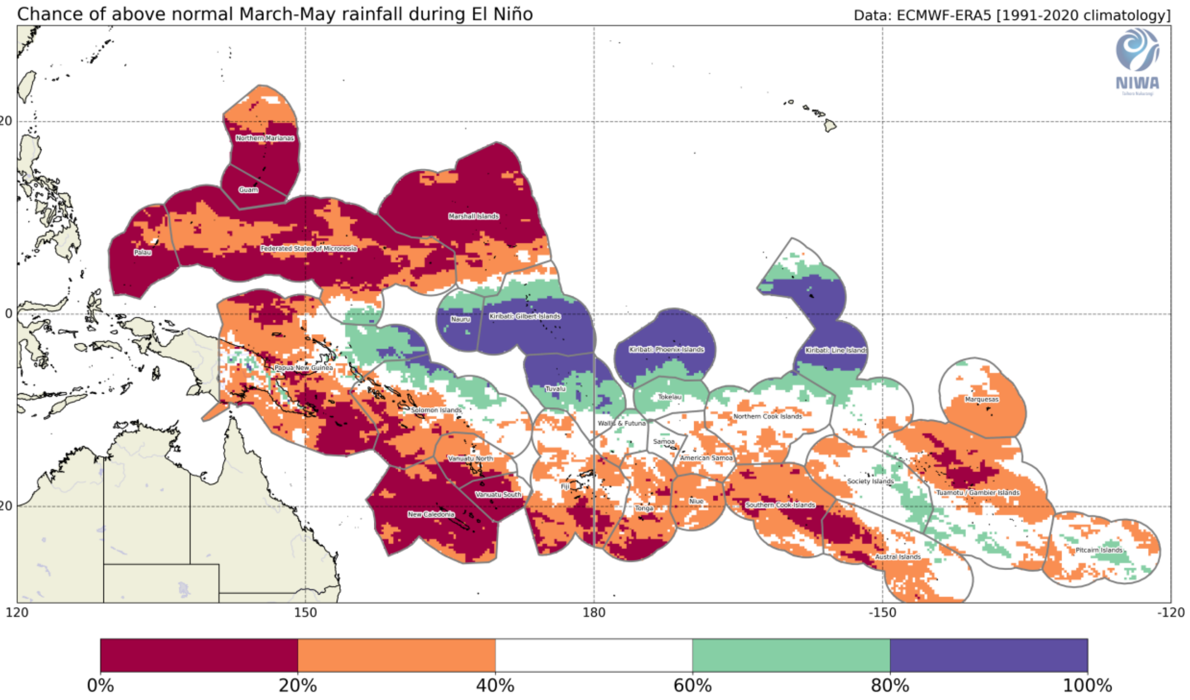
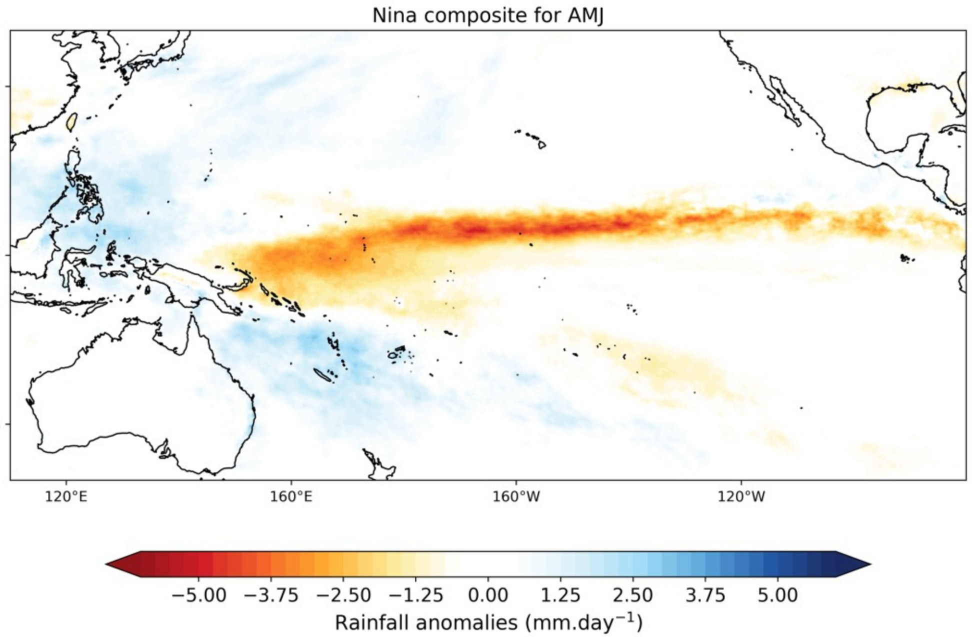
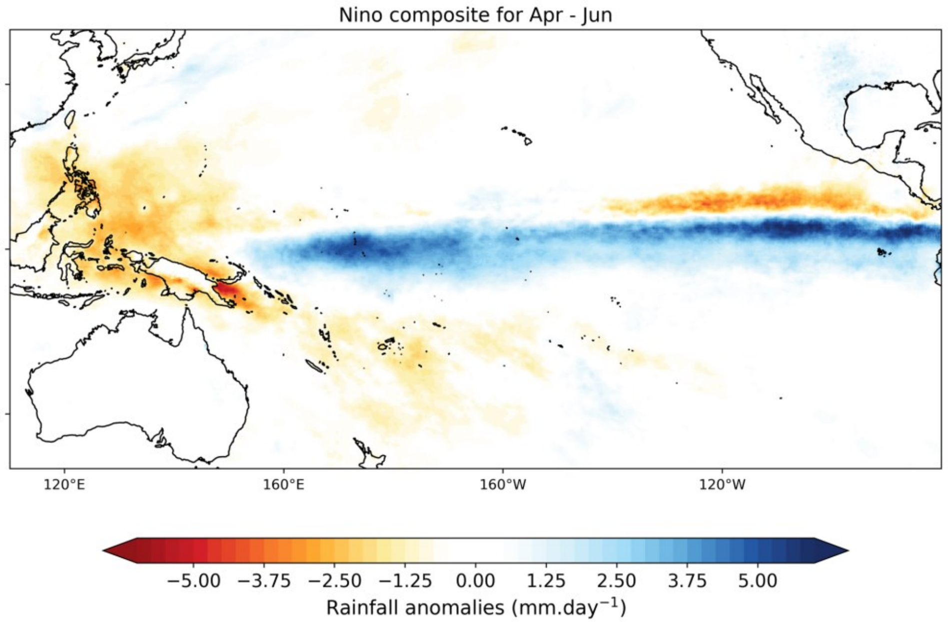

Chance of above normal March-May rainfall during La Niña
Data: ECMWF-ERA5 [1991-2020 climatology]
NIWA
20
0
-20
120
150
180
-150
-120
0%
20%
40%
60%
80%
100%

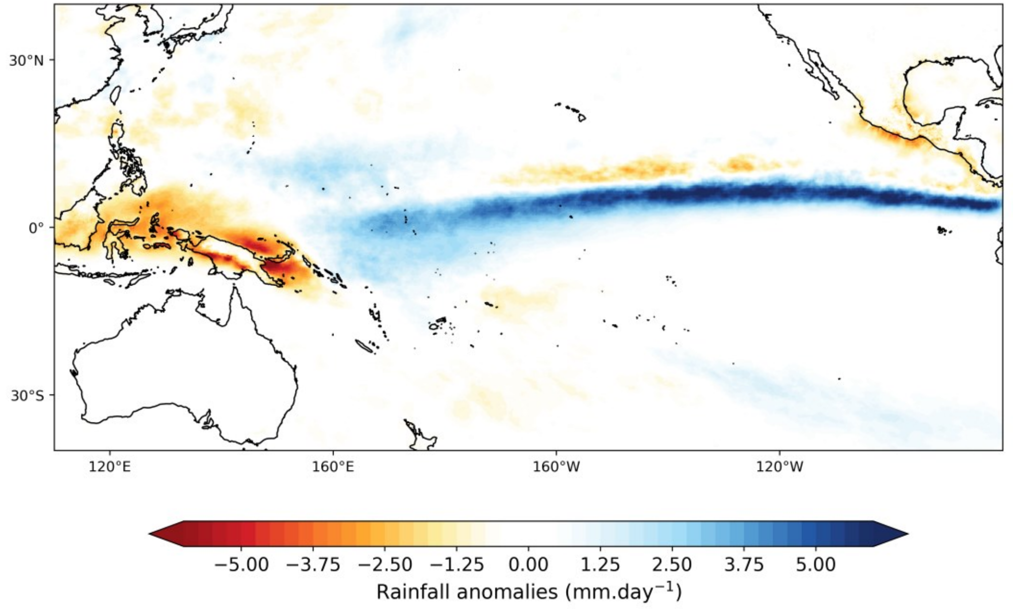

Chance of above normal March-May rainfall during El Niño
Data: ECMWF-ERA5 [1991-2020 climatology]
NIWA
20
0
-20
120
150
180
-150
-120
0%
20%
40%
60%
80%
100%


Nina composite for AMJ
30°N
0°
30°S
120°E
160°E
160°W
120°W
−5.00 −3.75 −2.50 −1.25 0.00 1.25 2.50 3.75 5.00
Rainfall anomalies (mm.day$^{-1}$)

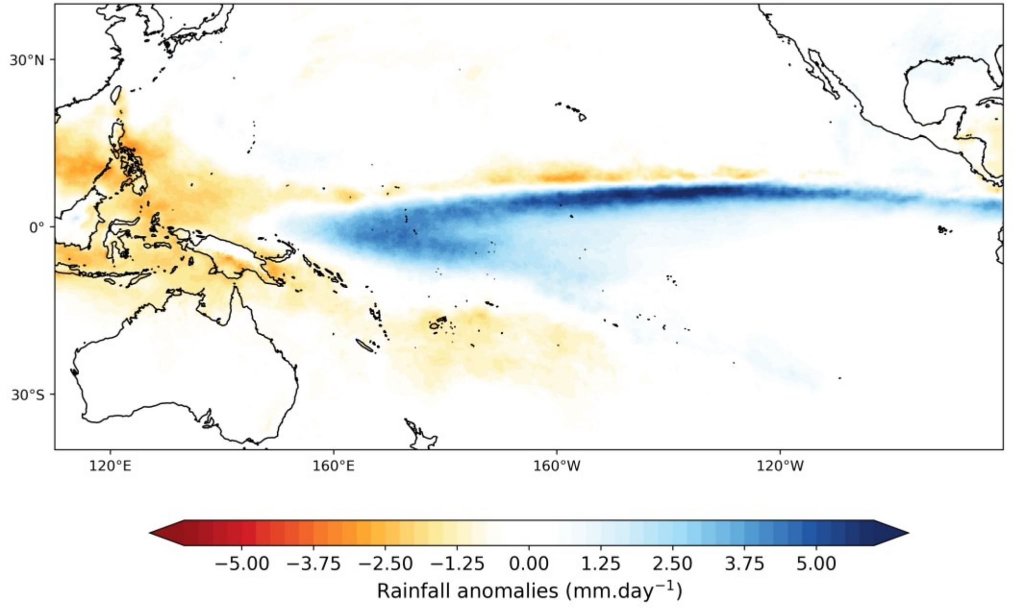

Nino composite for Apr - Jun
30°N
0°
30°S
120°E
160°E
160°W
120°W
−5.00 −3.75 −2.50 −1.25 0.00 1.25 2.50 3.75 5.00
Rainfall anomalies (mm.day$^{-1}$)

# NINO composite anomalies

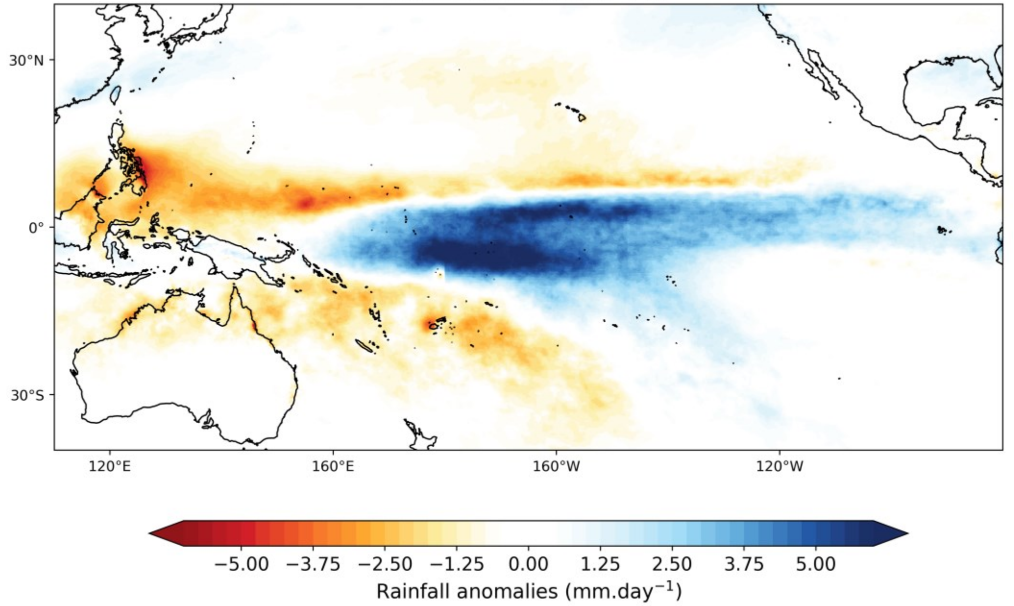
## July - September



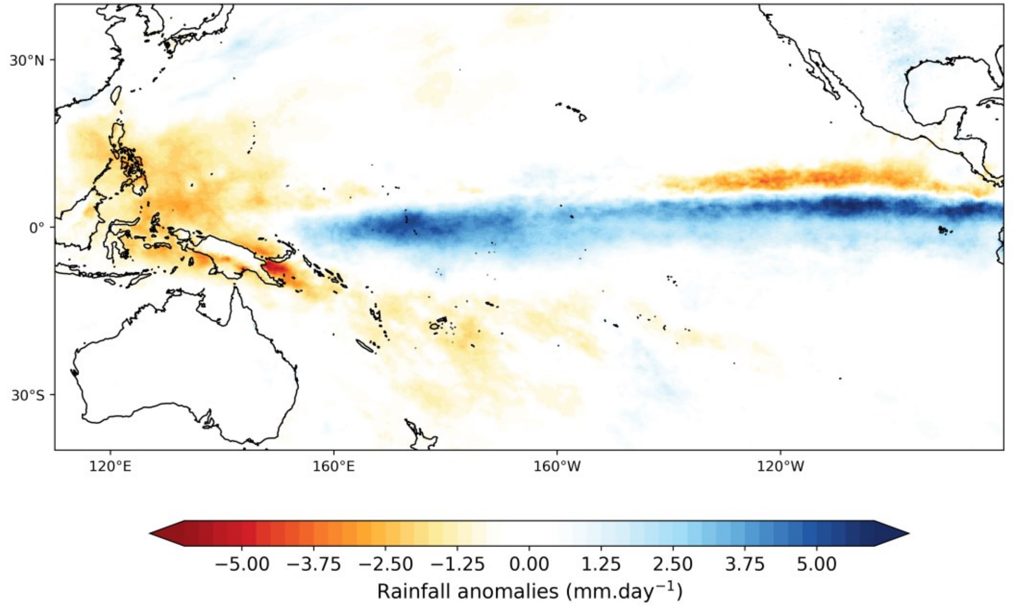

## October - December



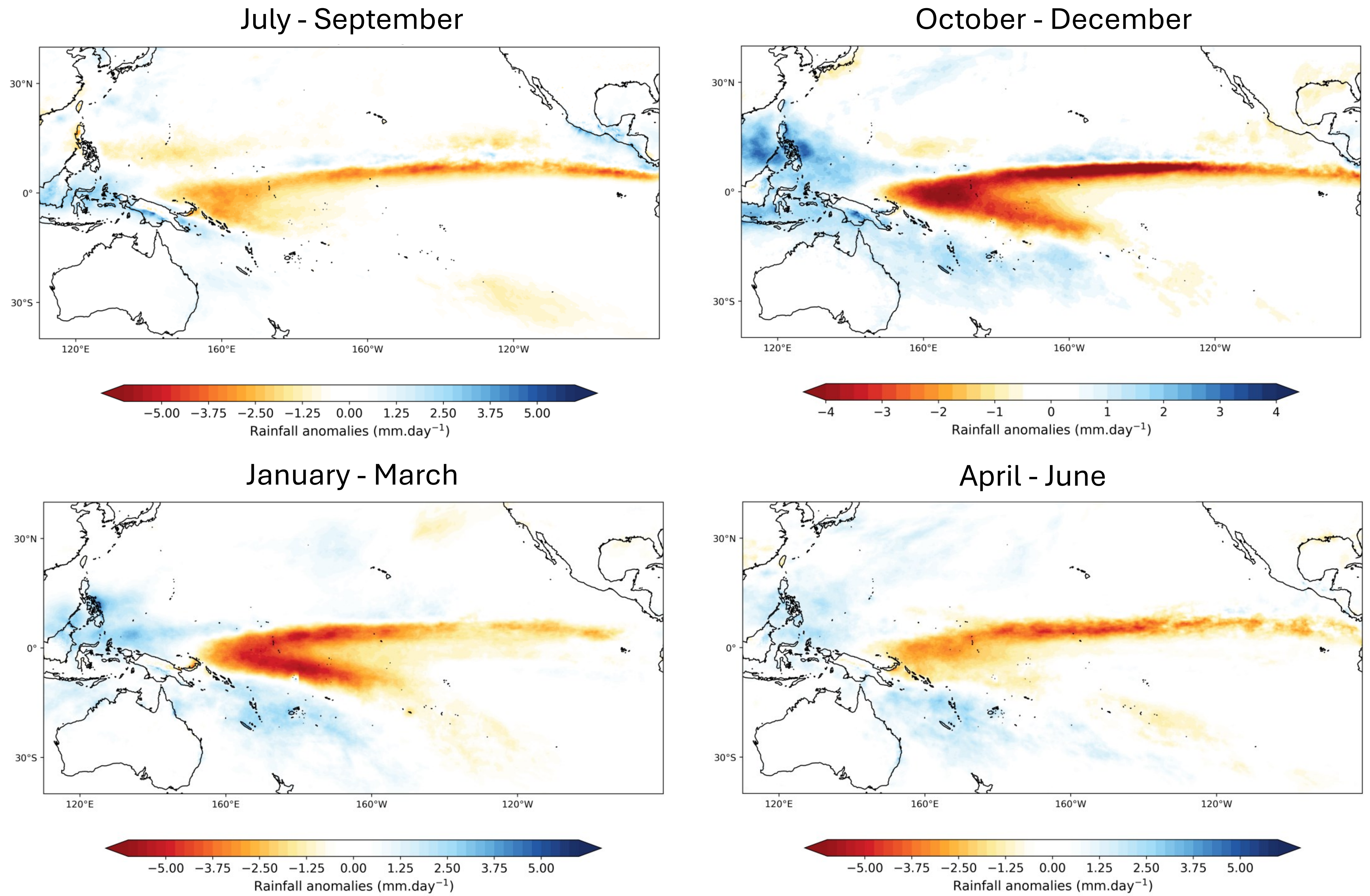

## January - March




## April - June



# NINA composite anomalies



# Data source and methodologies for the Tokelau NCOF climate products page

https://nicolasfauchereau.github.io/Tokelau_NCOF/

NOTE: This URL might change / be duplicated in the future and hosted from www.niwa.co.nz

# Climate Monitoring

## Sea Surface Temperatures (SSTs)

Data comes from **5km** resolution satellite observations available from the **NOAA Coral Reef Watch product**

NOAA Coral Reef Watch Homepage and Near Real-Time Products Portal

**https://coralreefwatch.noaa.gov/product/5km/index.php**

**Climatology** has been updated for Tokelau compared to the NOAA product, now is **1991 – 2020**

Data is downloaded and processed every day

Anomalies are calculated WRT each day of the year, with a 15 days buffer (e.g. climatology for 1$^{st}$ of April is calculated using days running from 25 March to 8 April)

Periods available 1, 7 and 30 days averages (date is always the *last* date of the period, i.e. 30 days ending on that date)

# Climate Monitoring

## Rainfall

Data comes from 1/10 of a degree **MSWEP** (Multi-Scale Weighted Ensemble Precipitation) dataset **version 2.8.0**

https://www.gloh2o.org/mswep/

MSWEP will transition to **version 3** (MSWEP 3.0) which requires **a paid license**

We have secured a perpetual license for Tokelau Meteorological Services, but restrictions (no 'raw' data to be provided)

**Climatology** is **1991 – 2020**

Data is downloaded and processed every day

Anomalies are calculated WRT each day of the year, with a 15 days buffer (e.g. climatology for 1$^{st}$ of April is calculated using days running from 25 March to 8 April)

Periods available 1, 30, 60, 90, 180, 360 days accumulations (date is always the *last* date of the period, i.e. 30 days ending on that date)

# Climate Forecasting

## Monthly and Seasonal Rainfall and SST forecasts

Data comes from the Copernicus Climate Change Service “Climate Data Store” (CDS)

**9 different General Circulation Models, latest versions**

'ecmwf' = 51
'ukmo' = 604
'meteo_france' = 8
'dwd' = 21
'cmcc' = 35
'ncep' = 2
'jma' = 3
'eccc_CanESM5.1p1bc' = 4
'eccc_GEM5.2-NEMO' = 5

**550 + ensemble members**

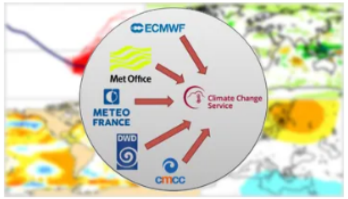
Forecast systems normally **initialised** on the 1$^{st}$ of each month, and made available on the 11, with NIWA processing occurring thereafter, ICU is usually updated on the 13$^{th}$

Copernicus CLIMATE DATA STORE
https://cds.climate.copernicus.eu/

# Seasonal forecast monthly statistics on single levels

Overview | Download | Quality | Documentation

This entry covers **single-level data** aggregated on a **monthly time resolution.**




**Seasonal forecasts** provide a long-range outlook of changes in the Earth system over periods of a few weeks or months, as a result of predictable changes in some of the slow-varying components of the system. For example, ocean temperatures typically vary slowly, on timescales of weeks or months; as the ocean has an impact on the overlaying atmosphere, the variability of its properties (e.g. temperature) can modify both local and remote atmospheric conditions. Such modifications of the 'usual' atmospheric conditions are the essence of all long-range (e.g. seasonal) forecasts. This is different from a weather forecast, which gives a lot more precise detail - both in time and space - of the evolution of the state of the atmosphere over a few days into the future. Beyond a few days, the chaotic nature of the atmosphere limits the possibility to predict precise changes at local scales. This is one of the reasons long-range forecasts of atmospheric conditions have large uncertainties. To quantify such uncertainties, long-range forecasts use ensembles, and meaningful forecast products reflect a distributions of outcomes.

Given the complex, non-linear interactions between the individual components of the Earth system, the best tools for long-range forecasting are climate models which include as many of the key components of the system and possible; typically, such models include representations of the atmosphere, ocean and land surface. These models are initialised with data describing the state of the system at the starting point of the forecast, and used to predict the evolution of this state in time. While uncertainties coming from imperfect knowledge of the initial conditions of the components of the Earth system can be described with the use of ensembles, uncertainty arising from approximations made in the models are very much dependent on the choice of model. A convenient way to quantify the effect of these approximations is to combine outputs from several models, independently developed, initialised and operated.

To this effect, the C3S provides a **multi-system seasonal forecast service**, where data produced by state-of-the-art seasonal forecast systems developed, implemented and operated at forecast centres in several European countries is collected, processed and combined to enable user-relevant applications. The composition of the C3S seasonal multi-system and the full content of the database underpinning the service are described in the documentation. The data is grouped in several catalogue entries (CDS datasets), currently defined by the type of variable (single-level or multi-level, on pressure surfaces) and the level of post-processing applied (data at original time resolution, processing on temporal aggregation and post-processing related to bias adjustment).

The data includes forecasts created in real-time each month starting from the publication of this entry and retrospective forecasts (hindcasts) initialised over periods in the past specified in the documentation for each origin and system.

## Data description

| | |
|---|---|
| Data type | Gridded |
| Projection | Regular latitude-longitude grid |
| Horizontal coverage | Global |
| Horizontal resolution | 1° x 1° |
| Temporal coverage | 1993 to 2016 (hindcasts); 2017 to present (forecasts) |
| Temporal resolution | Monthly |

# **C3S Seasonal forecasts** data pipeline is **operational and supported 24/7**

**CDS**

Copernicus data store (CDS) releases seasonal forecast data once a month

**Parallelised Download**

**NIWA Supercomputing facilities**

Latests forecasts from each of the C3S MME (9 in total) is downloaded and is post-processed

**Cylc Polling**

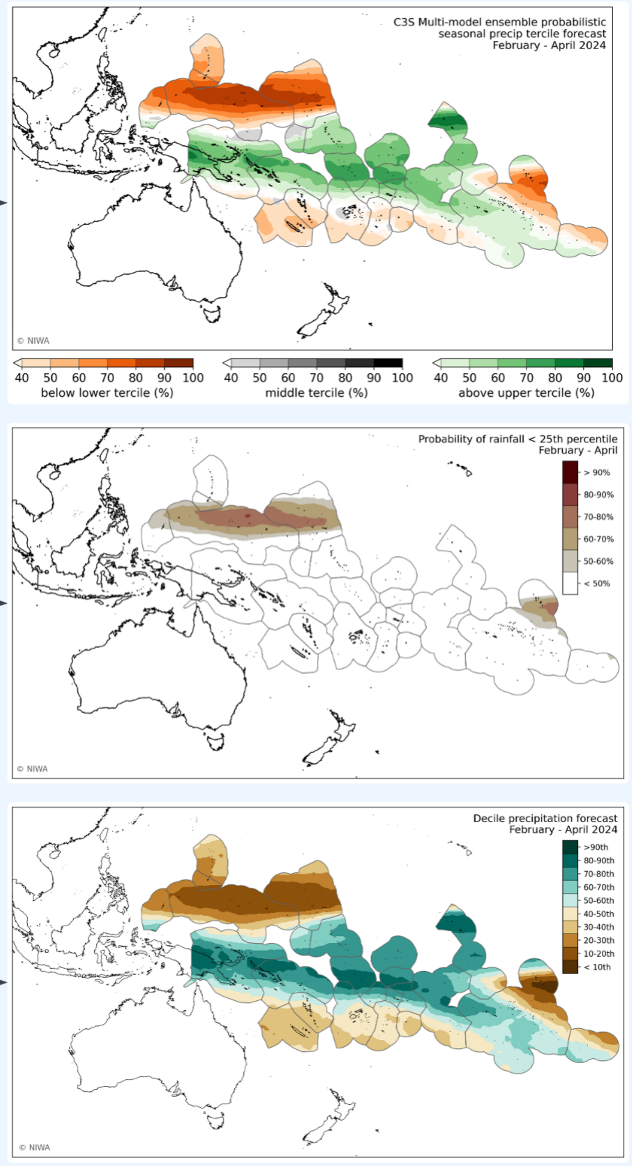
NIWA produces seasonal forecasts anomalies

**Reference data**

1993-2016 hindcast is downloaded and post-processed for the latest "system numbers" for each of the 9 C3S models.

**Image and netCDF outputs**

**THREDDS public data server, AWS S3 Bucket, RShiny website, and RCC-N website**



# Fakafetai !

Climate, Freshwater & Ocean Science

NIWA
Taihoro Nukurangi