2024 ENGINEERING INSTITUTION OF ZAMBIA SYMPOSIUM

The Physical Science Basis of El Niño-Southern Oscillation, its Impacts on Zambia, and How Engineers Can Respond

with

Eng. Cuthbert Casey Makondo (PhD)

Date: Friday 19th April 2024

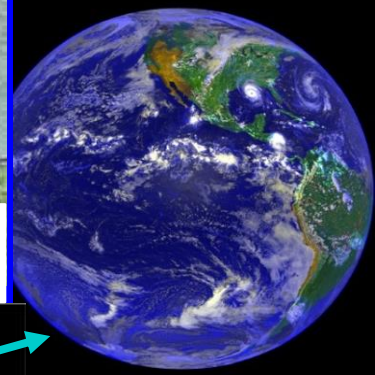
Place: Avani Victoria Falls Resort, Livingstone, Zambia

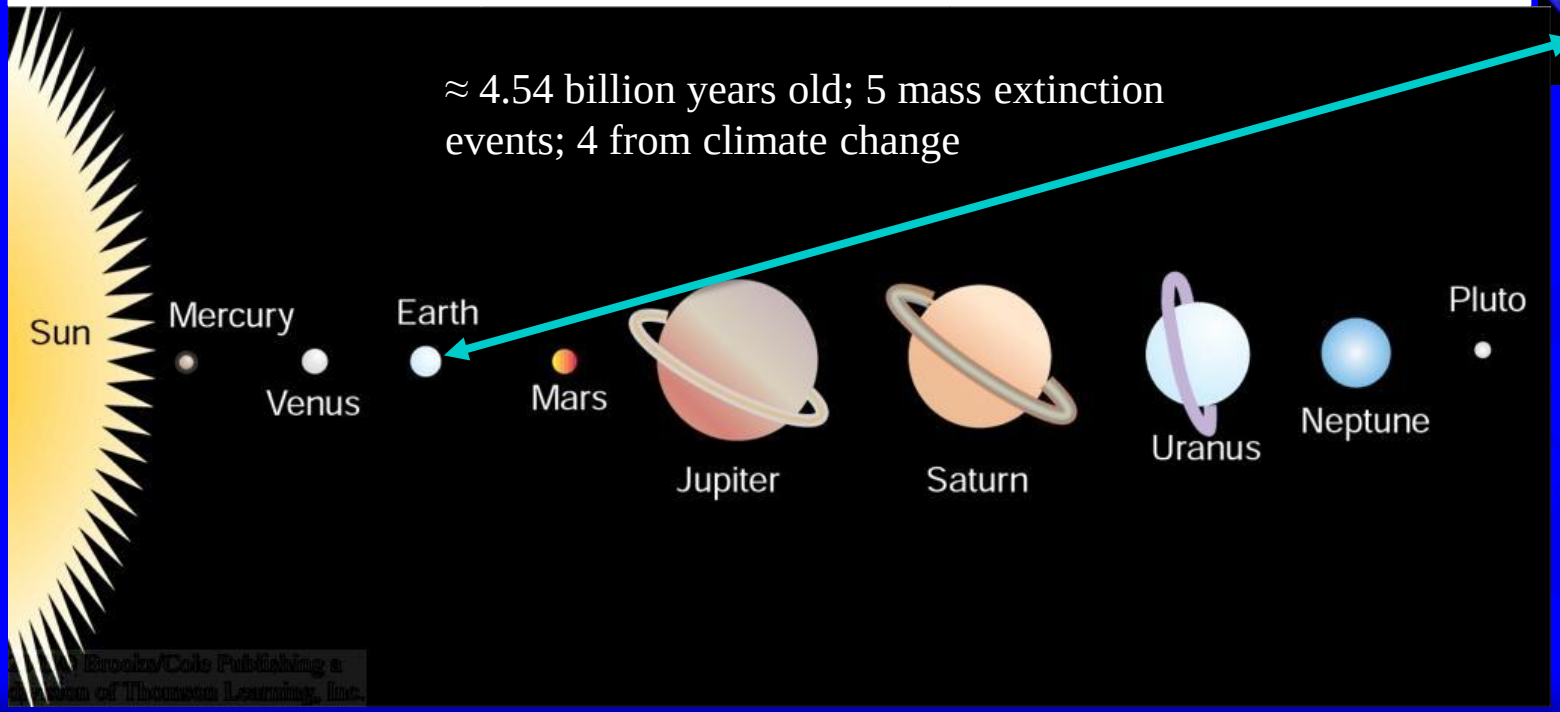
The Habitable Earth
(70% water, 30% Land)

≈ 350 million years old; survived 3 mass extinctions

≈ 230 million years old; survived 2 mass extinctions

≈ 225 million yrs old; survived 2 mass extinctions : humans ≈ 200,000 yrs old





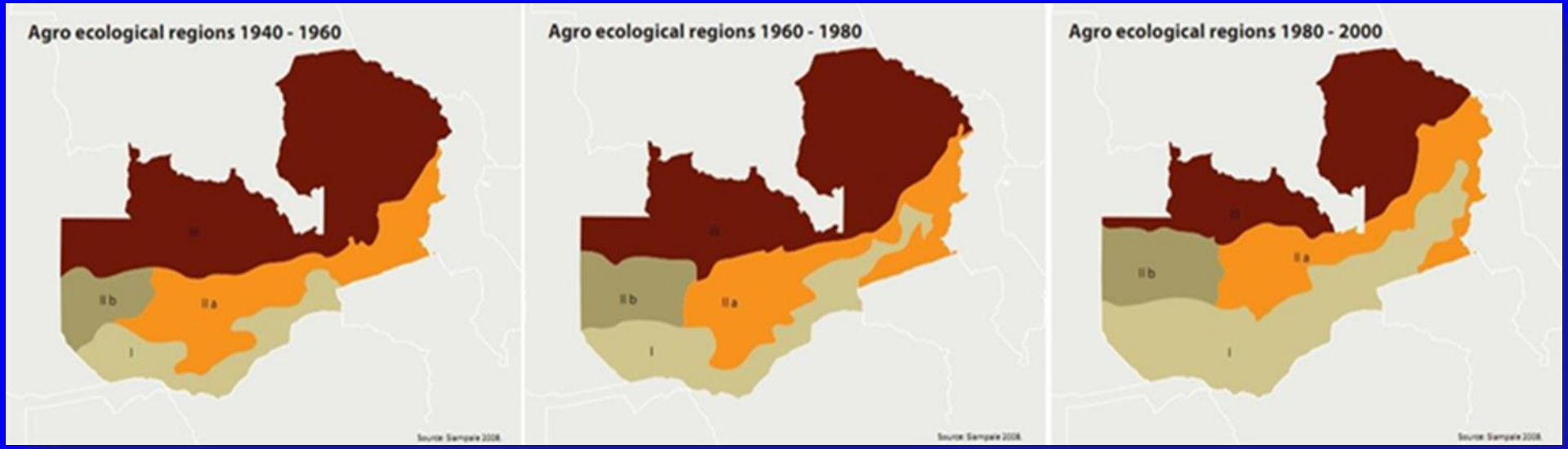
Fact File:

≈ 850 million people globally are already affected by extreme weather events (IPCC, 2014);

An additional ≈ 100 million people will be forced into extreme poverty globally by 2030 (World Bank, 2018);

The poor are the most affected as they have the least adaptive potential;

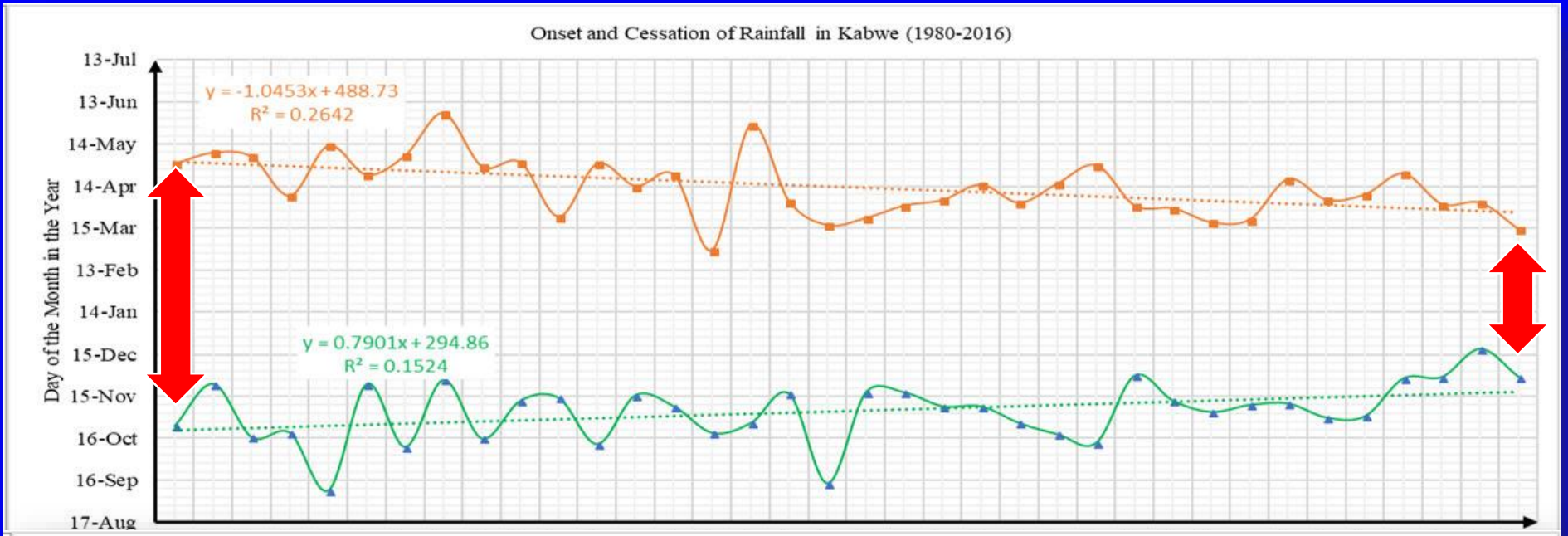
≈ 216 Million people globally will be forced into migration by 2050; ≈ 86 million in Sub-Saharan (UNDP, 2019).

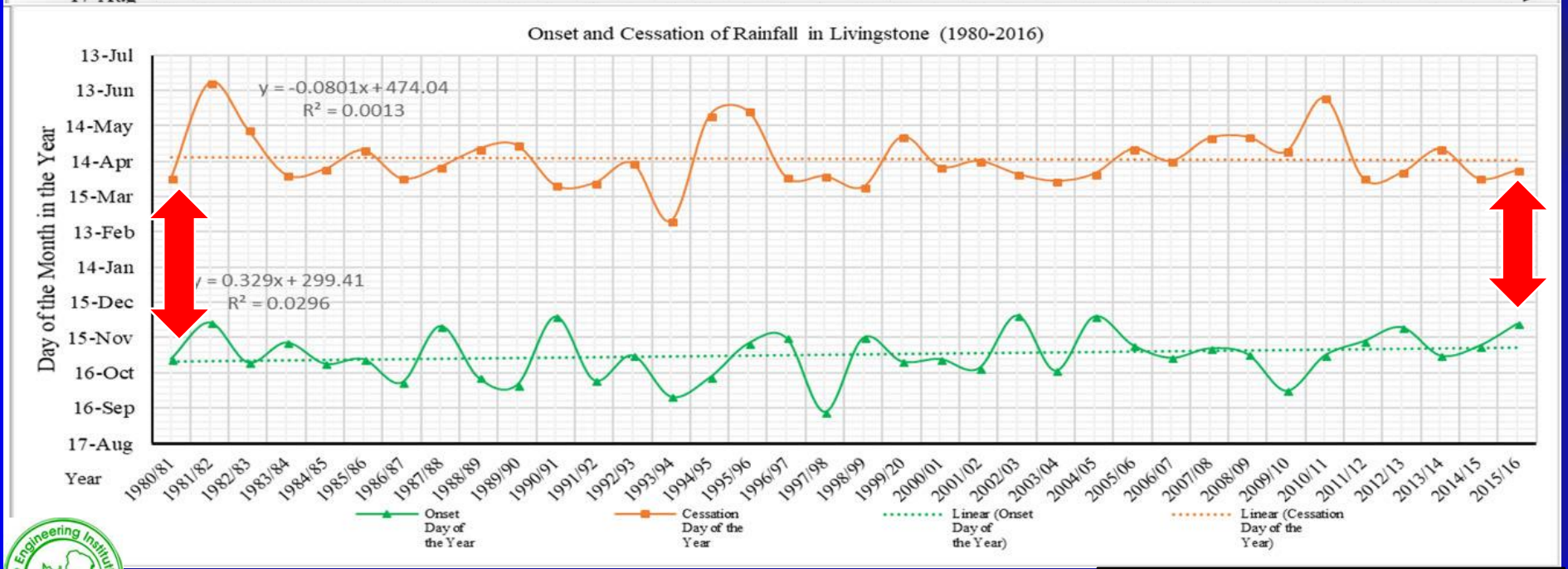


≈ 26,000 per every million people already living on environmentally degraded land in Zambia (UNDP, 2016)

CO_2 doubling scenario under changing climatic conditions extreme weather events expected to increase.

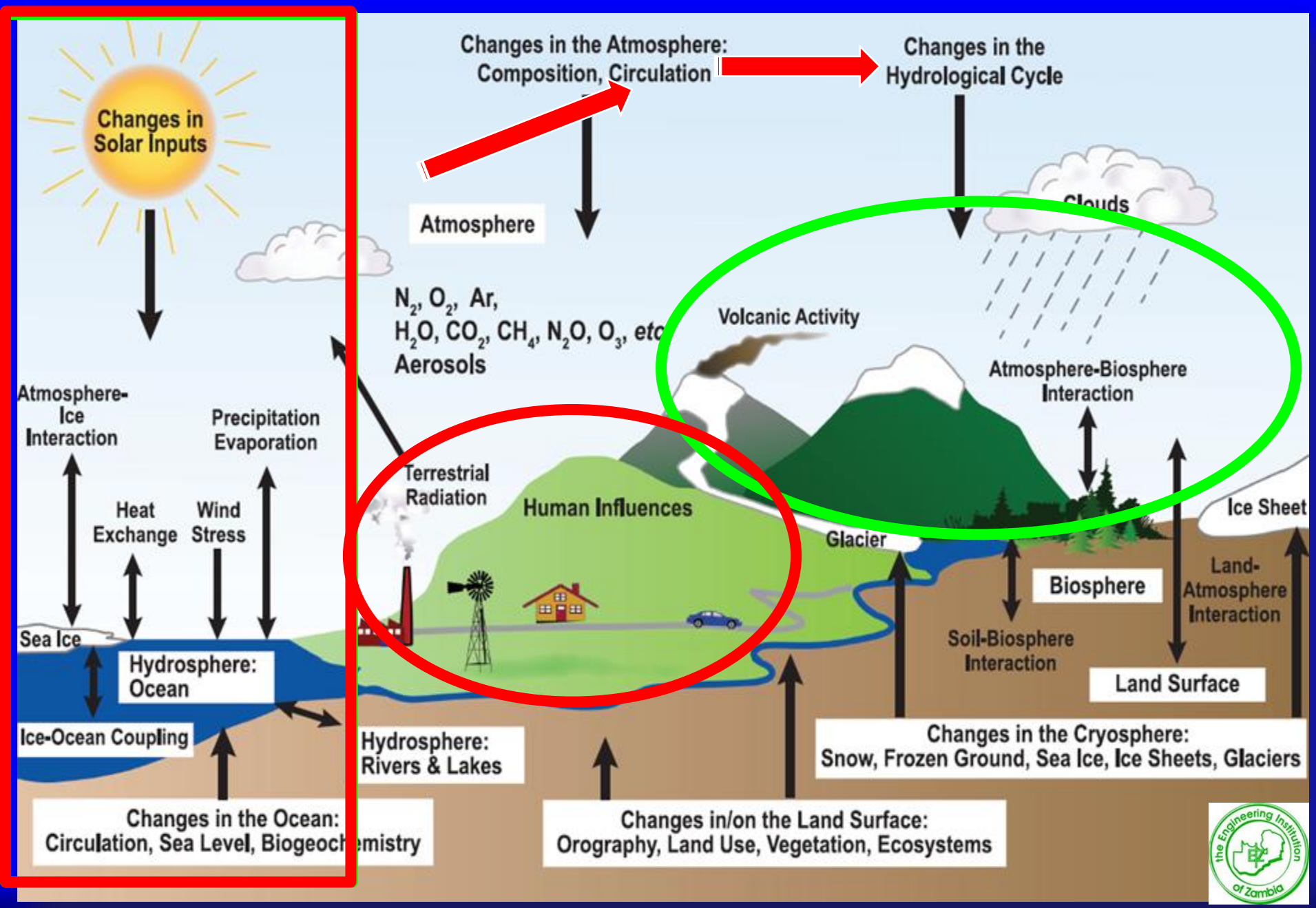
Estimates predict a crop yield reduction of ≈ 66 percent under rain-fed conditions by 2040 (Niang et al., 2014).





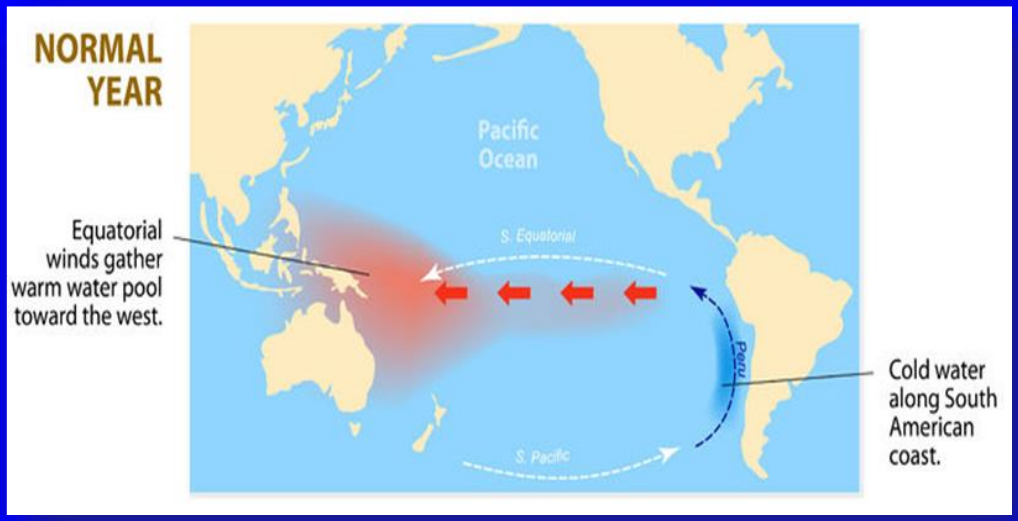
Source: Makondo and Thomas (2019)

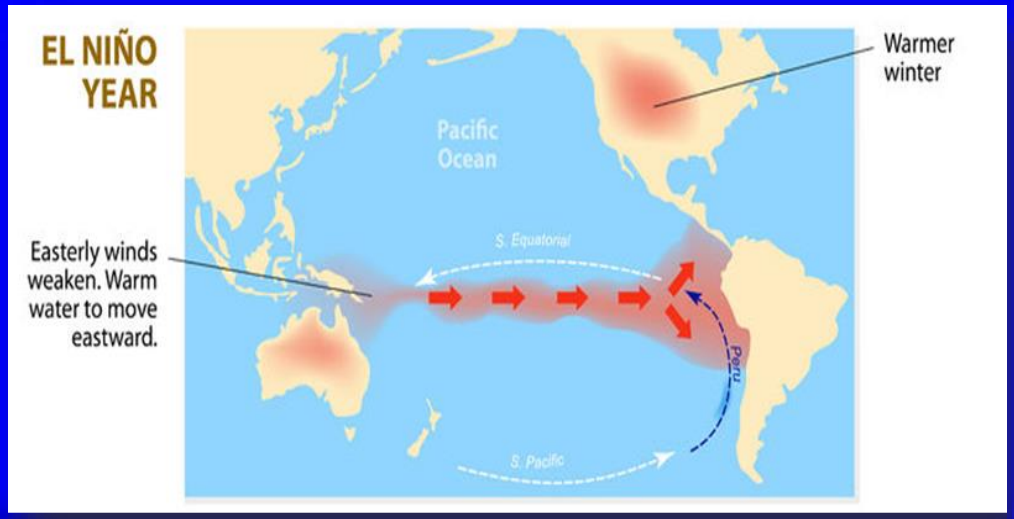
THE EARTH'S CLIMATE MECHANISM (IPCC, 2014)



El Niño-Southern Oscillation (ENSO)

- **El Niño** and **La Niña**; together, called **El Niño-Southern Oscillation (ENSO)** is a natural occurrence, arising from the tropical sea surface temperature change (Timmermann et al. 2018).
- Caused by Earth's atmospheric and sea interaction around the equatorial Pacific Ocean.
- ENSO has a significant influence on the global climate system and can significantly modify local climate.
- Has an irregular occurrence pattern that ranges from two to seven years (Gore et al. 2019).

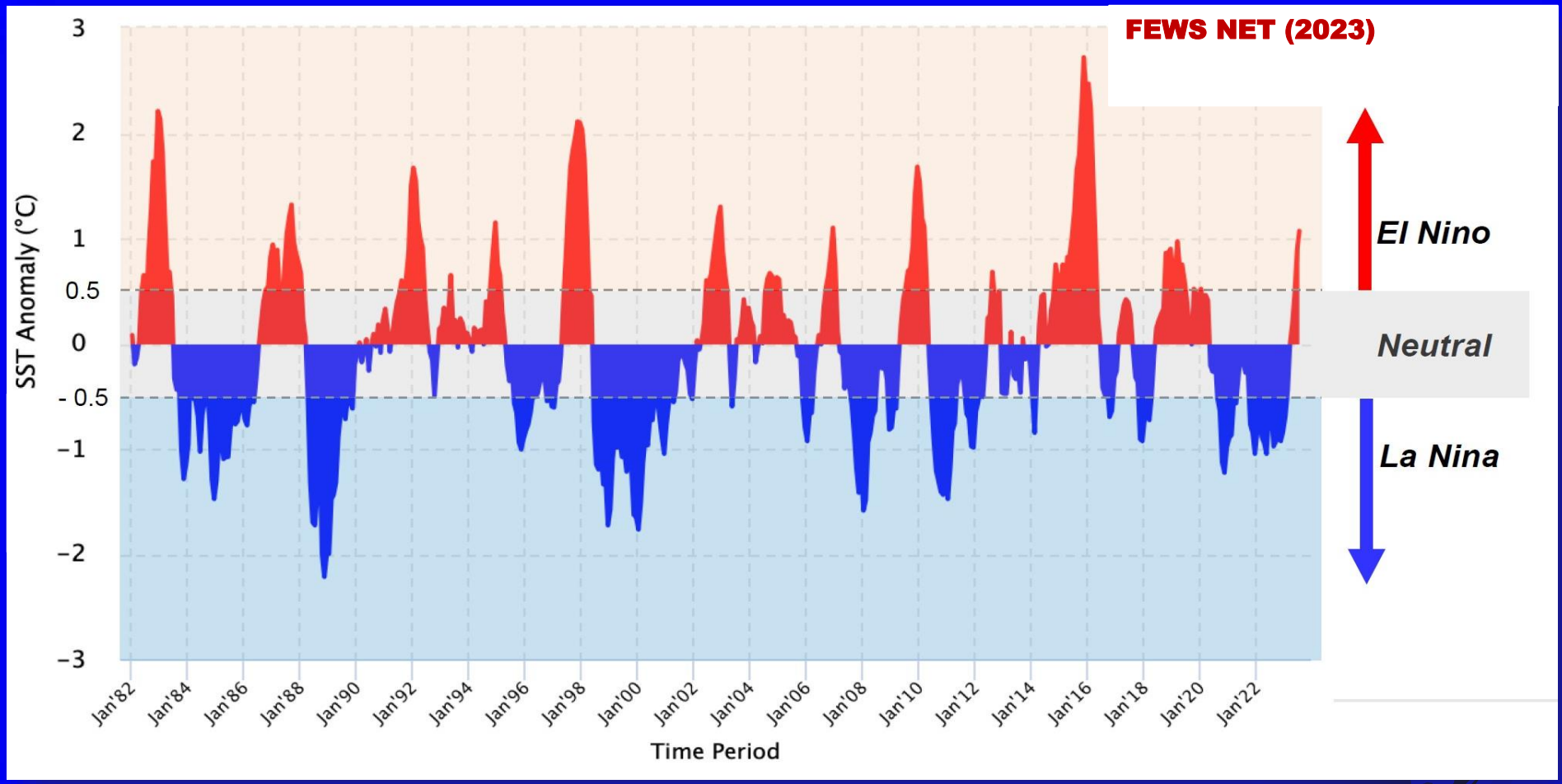




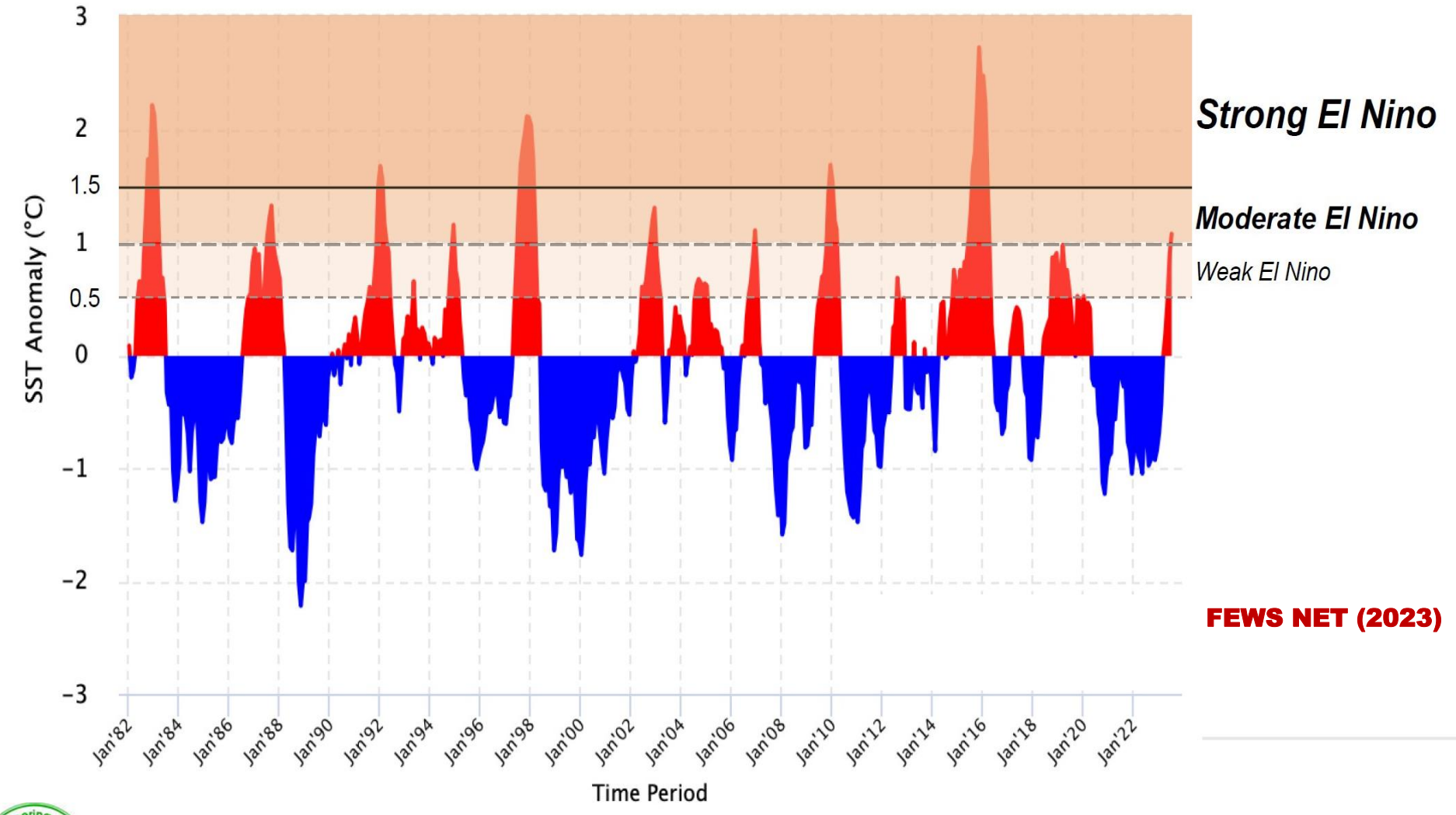
El Niño-Southern Oscillation (ENSO)

- In the ocean-atmospheric interaction, the sea surface temperature (SST) can rise or drop depending on:
  - incoming solar radiation intensity (Milankovitch Cycles),
  - sea water vertical mixing rates, and
  - the atmospheric pressure difference generated (Chen and Fang 2022).
- **El Niño** =higher sea level rises and warmer-than-average ocean temperatures
- **La Niña** =lower sea level sinks and cooler-than-average ocean temperatures
- Because they are opposite, the term **"oscillation"** is used to refer to the climate system swings

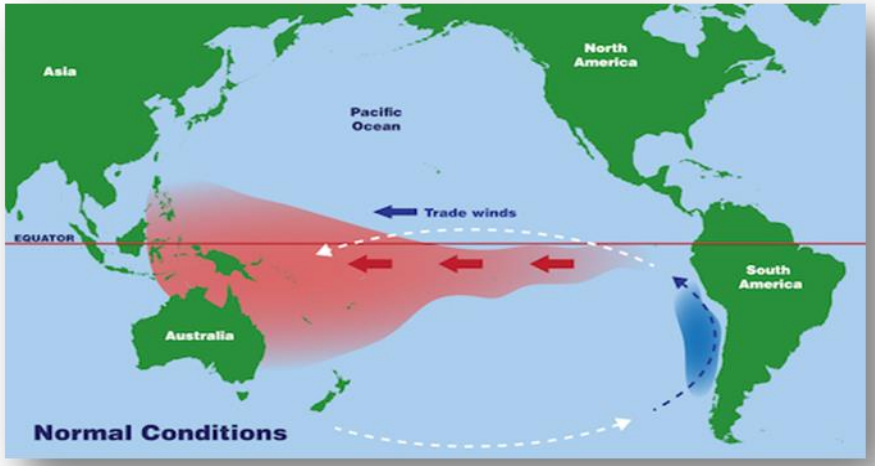
How ENSO is Monitored

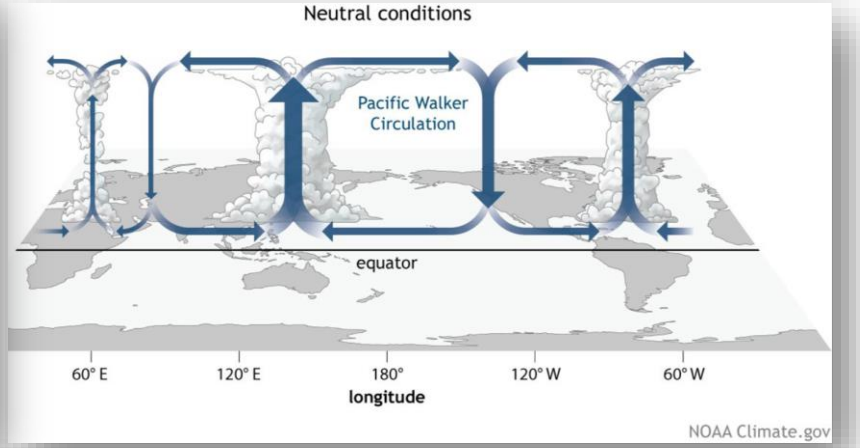


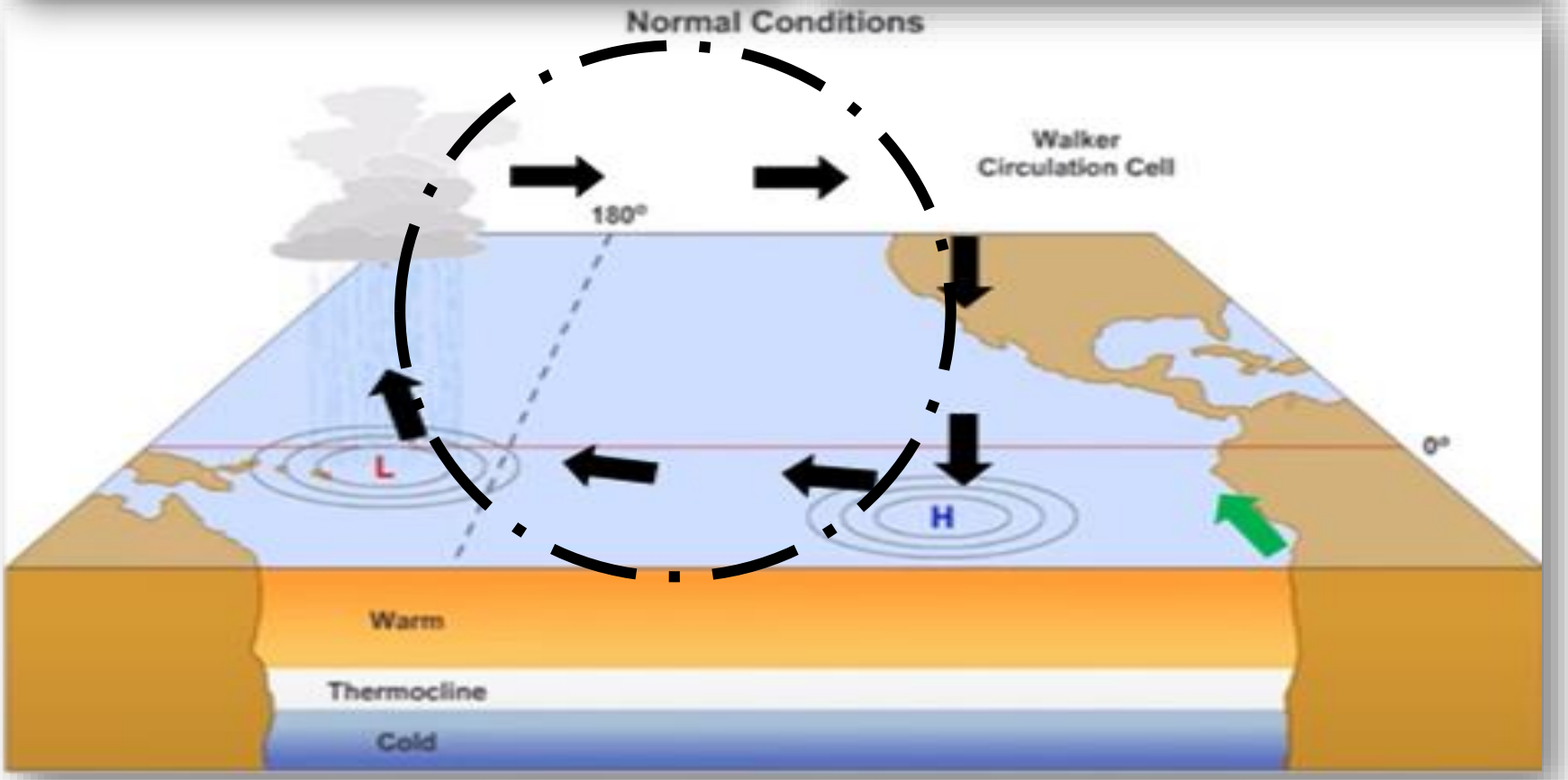
Measuring ENSO Strength



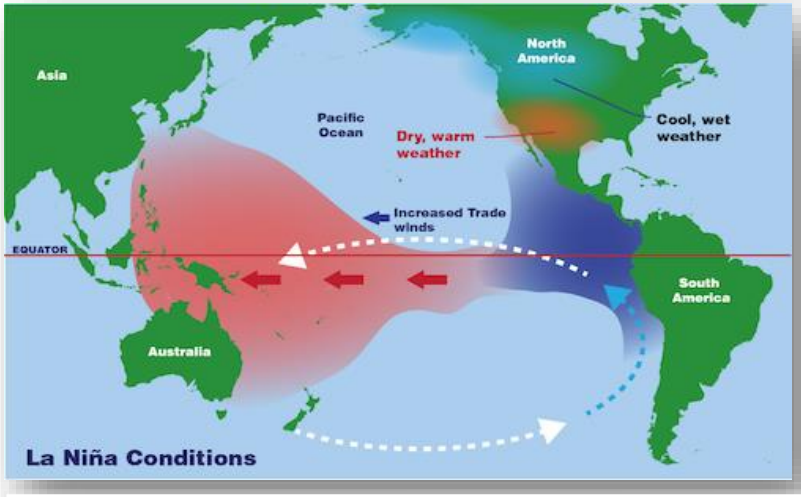
FEWS NET (2023)

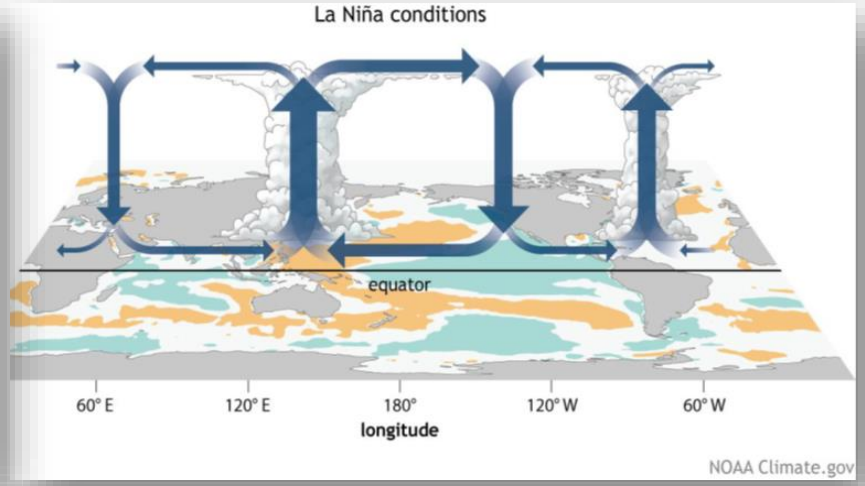


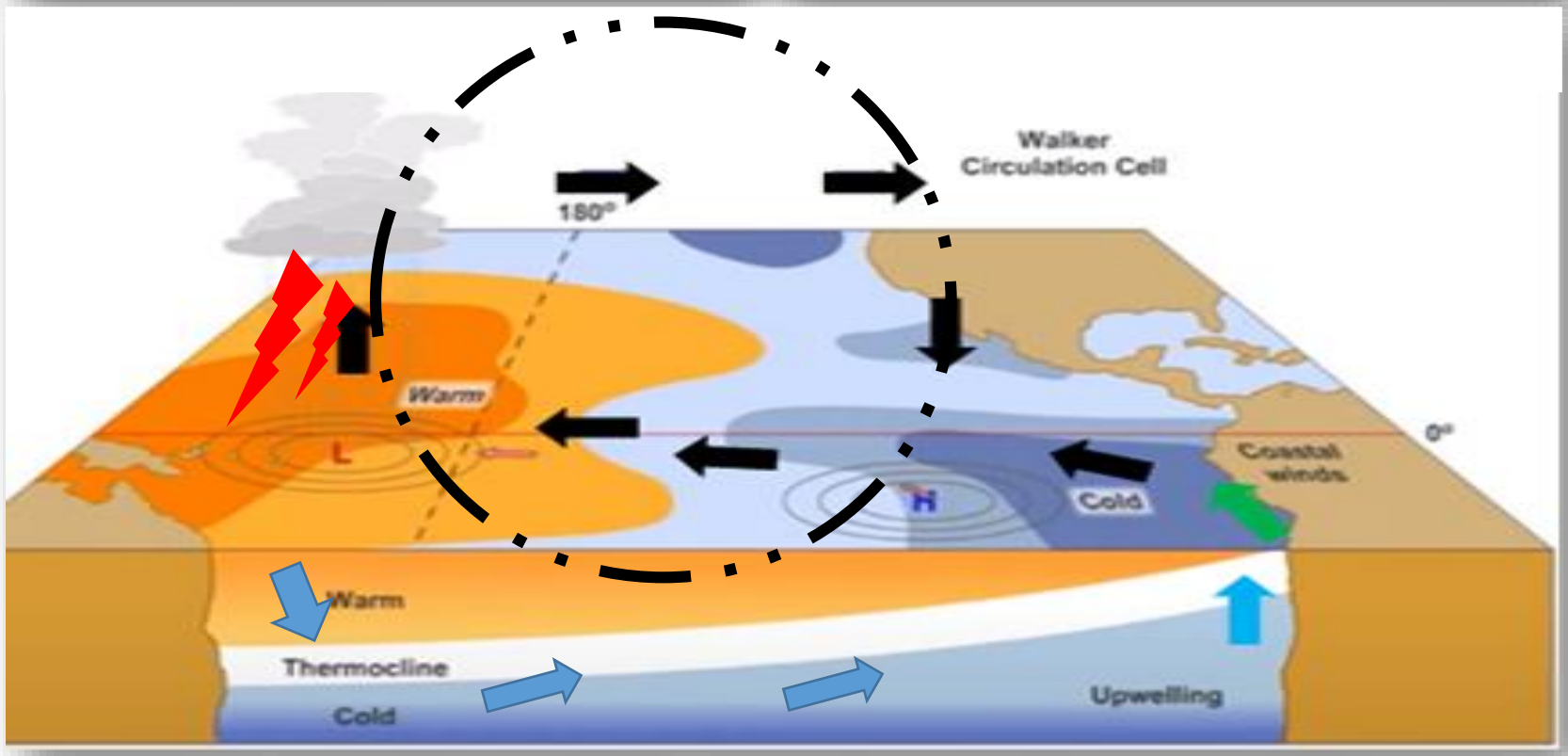




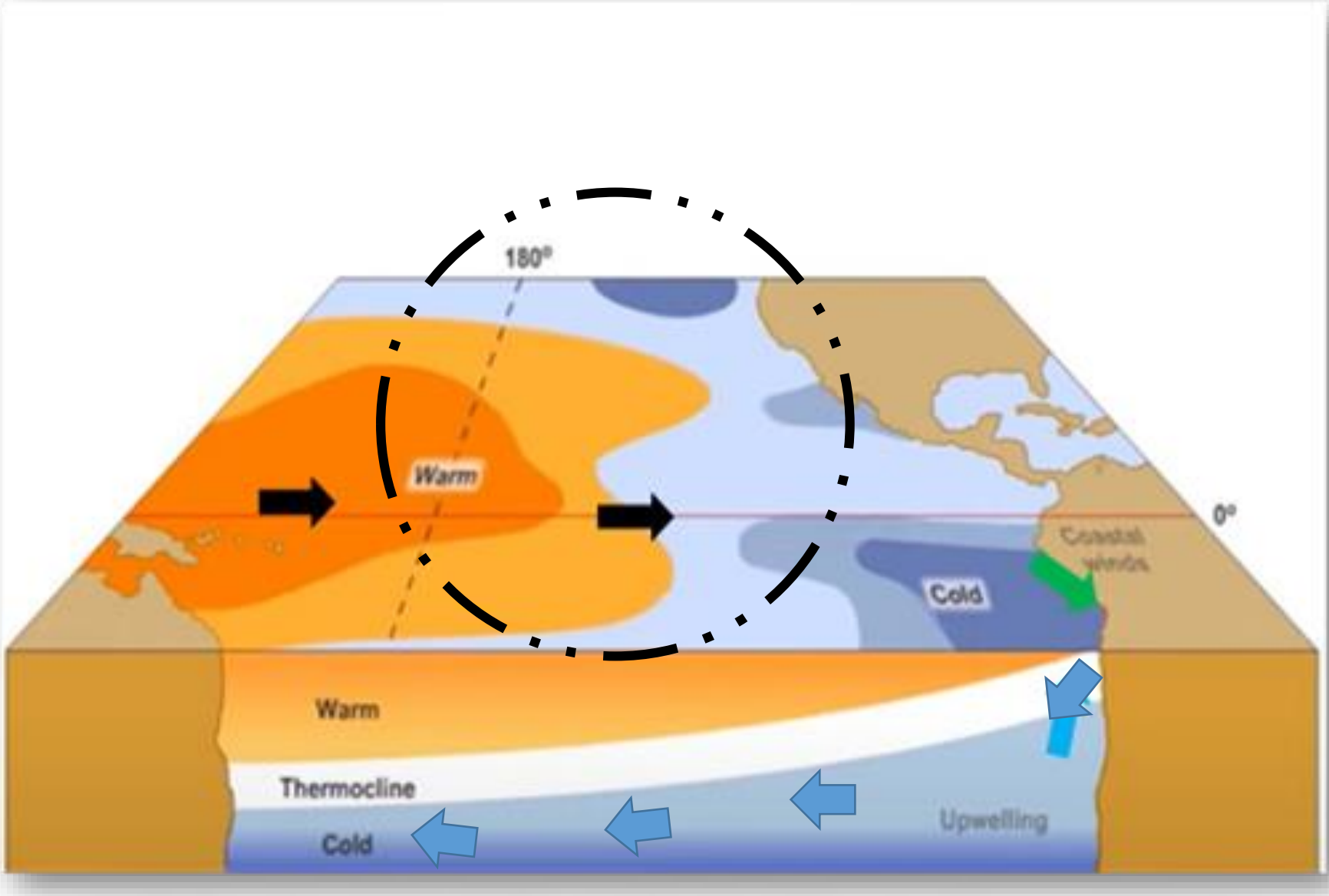
A) Normal Conditions: Neither El Niño nor La Niña event



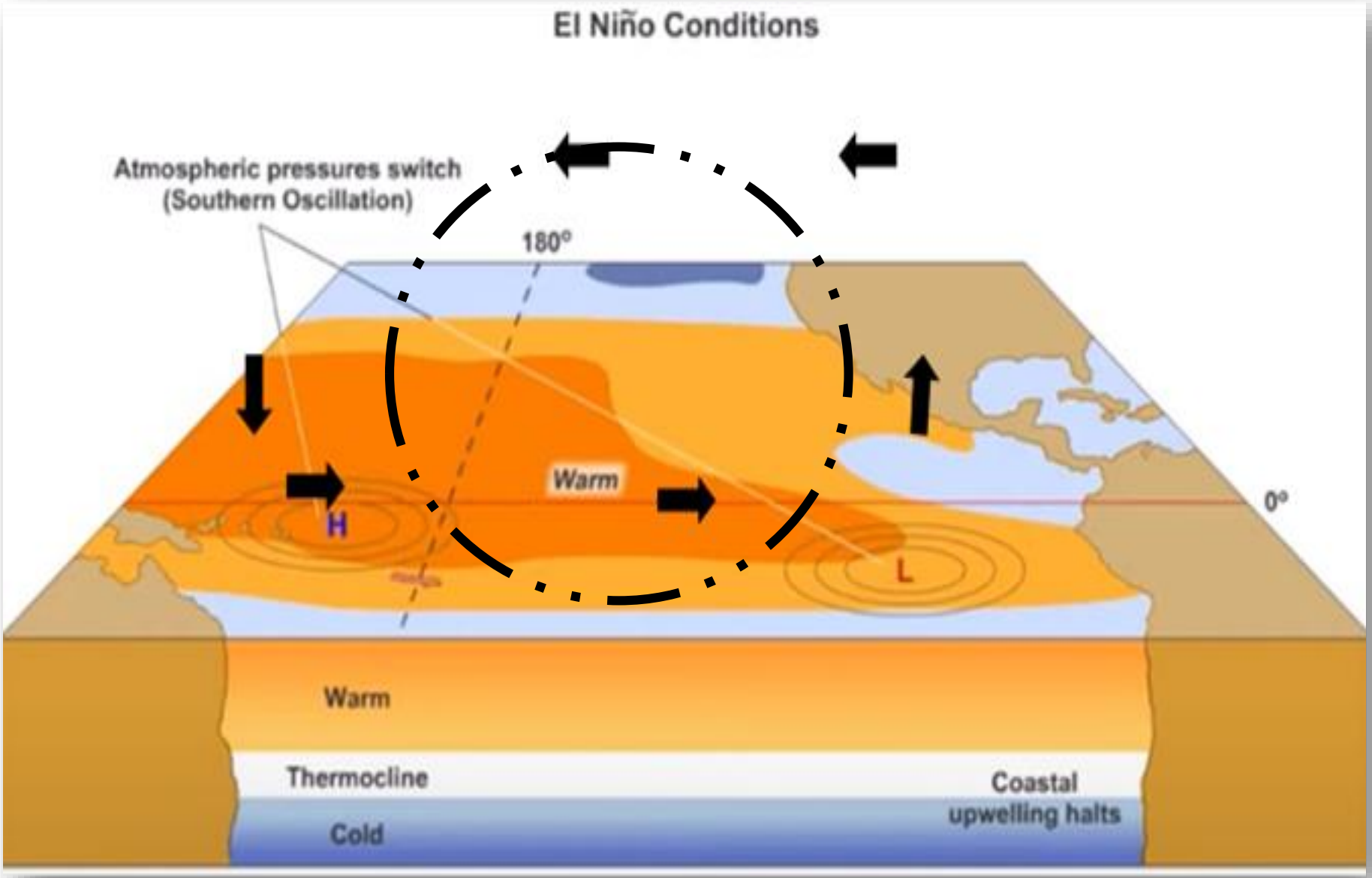




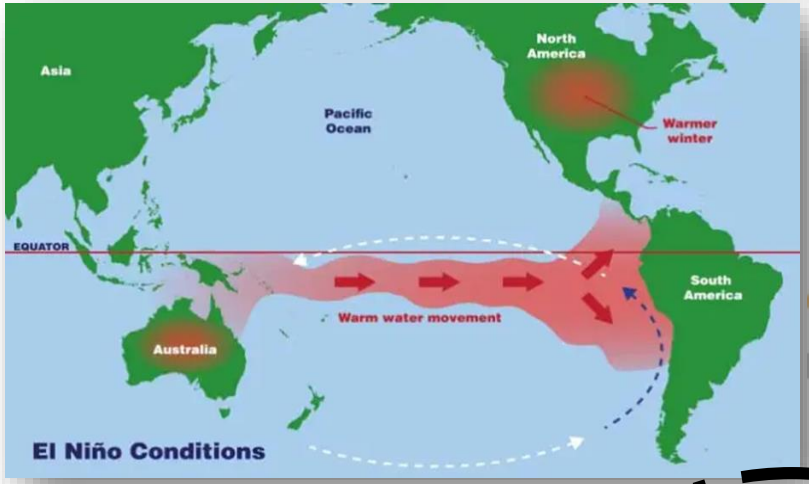
B) From normal to La Niña event (increased pressure difference)

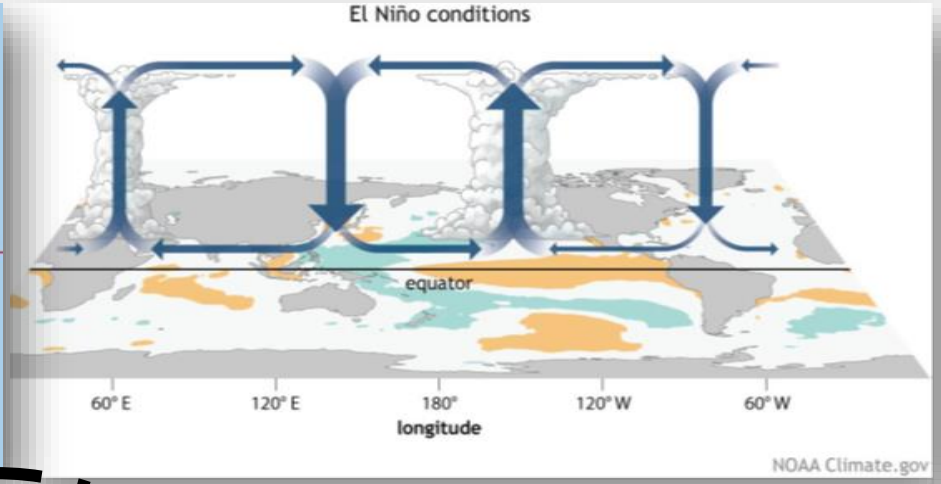


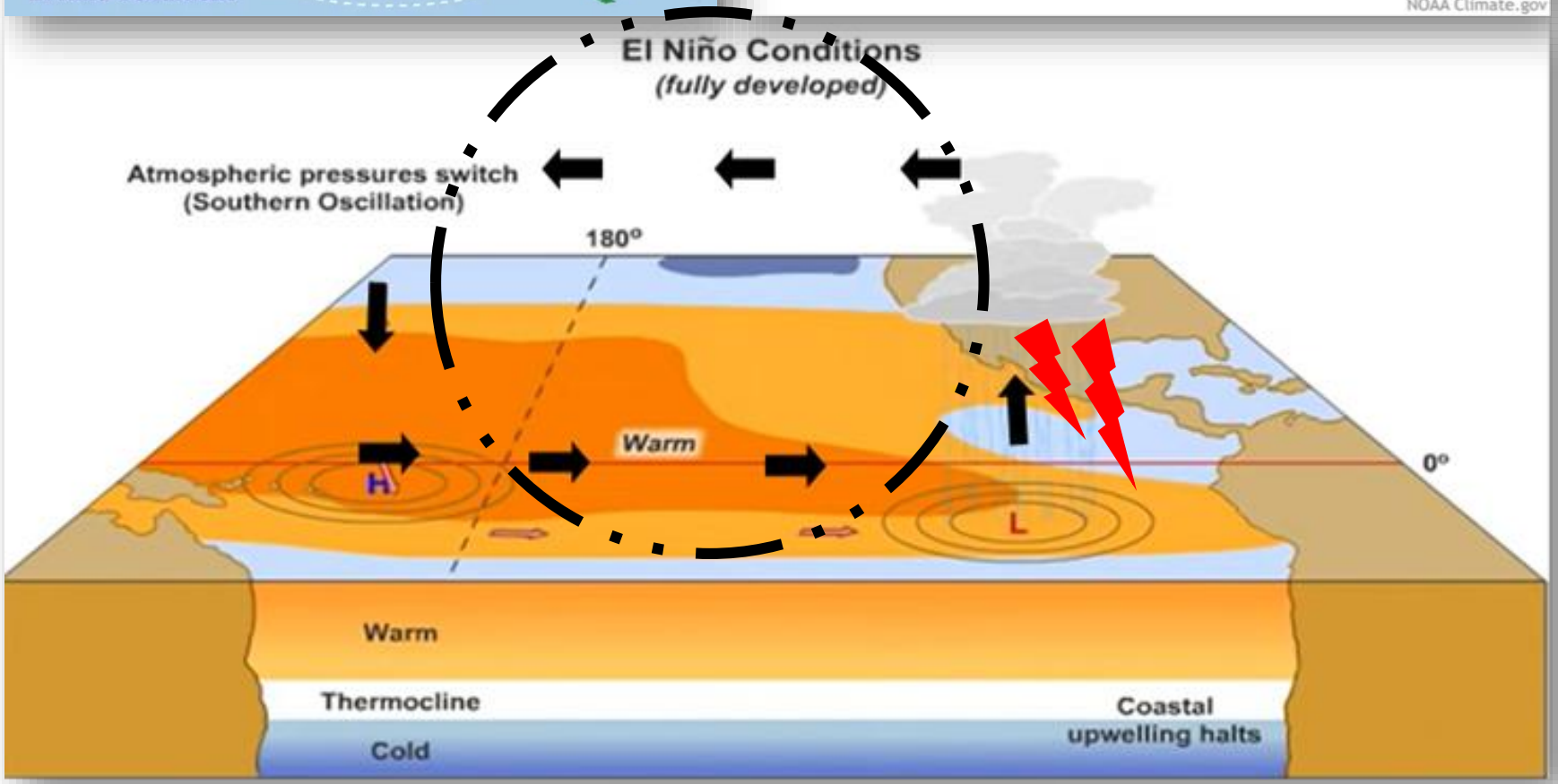
C) Walker Circulation Cell neutralized and the opposite scenario begins to develop : Southern Oscillation, with possible transition to El Niño



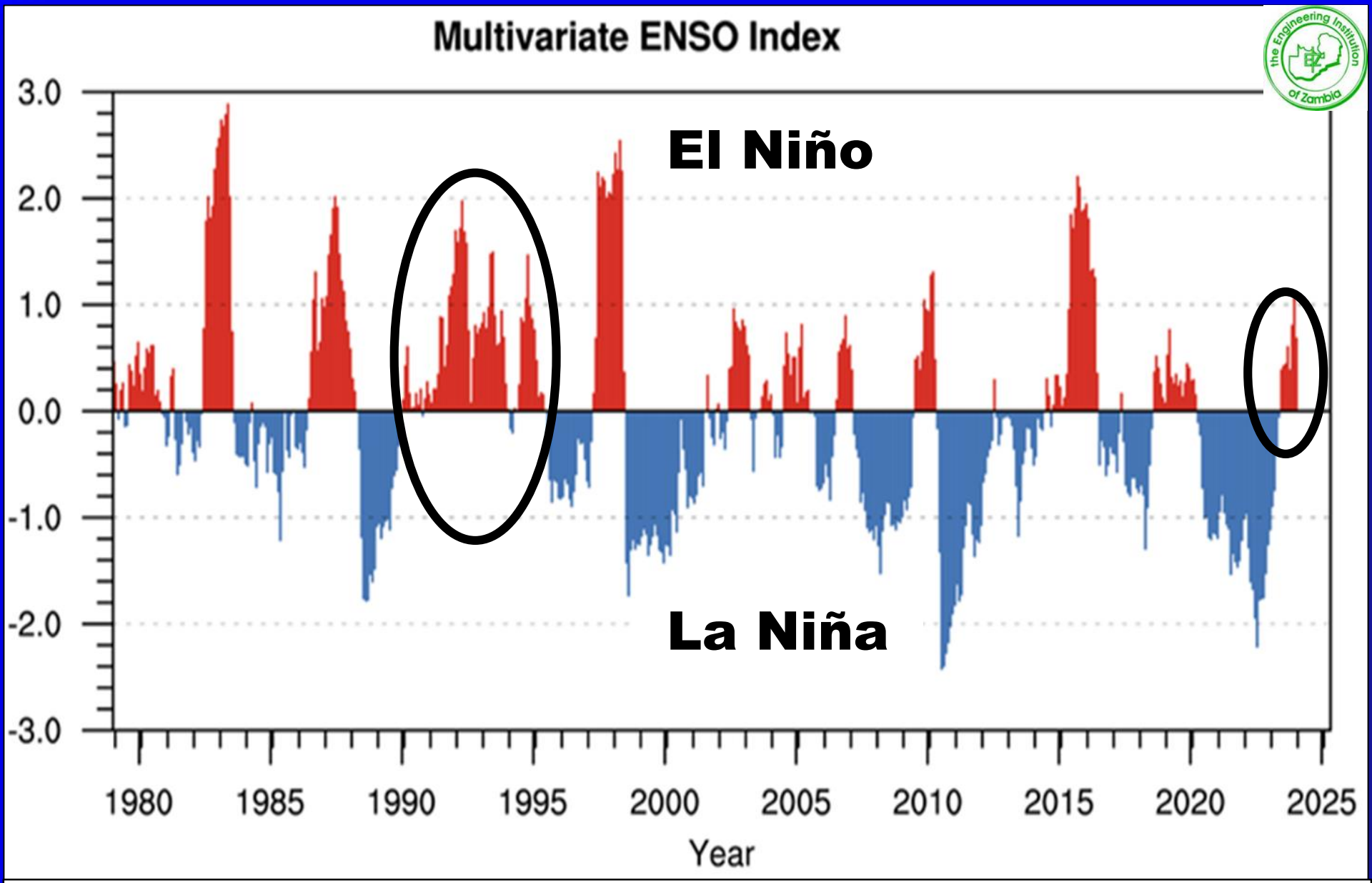
D) Southern Oscillation strengthens to El Niño







E) Fully developed El Niño event

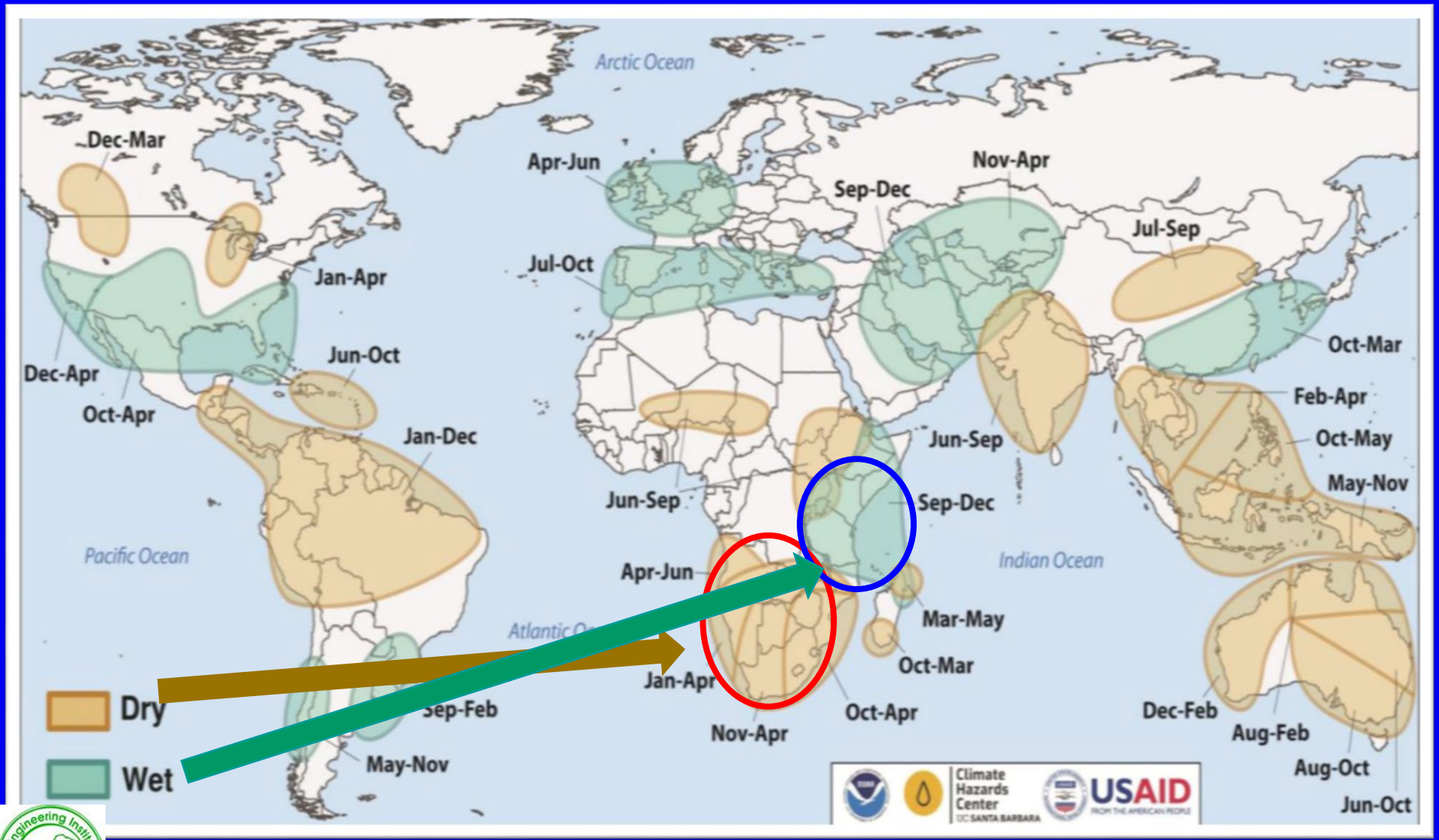


NOAA Data/Re-analysis with MEI V2: Primary Data: RA55 (1980 - 2024)

Selected Top 8 ENSO Events in Chronological Order,1877-2011 (Processed from NOAA- Physical Science Lab)

S/no.	El Niño	La Niña
1	1877-78	1889-90
2	1888-89	1973-74
3	1930-31	1975-76
4	1965-66	1988-89
5	1972-73	1997-98
6	1982-83	1998-99
7	1991-92	2007-08
8	1997-98	2009-10

Global Precipitation Patterns During Active El Niño Conditions



El Niño Impacts on Zambia

La Niña Impacts on Zambia

Impacts on Zambia's Rainfall

1

El Niño

During El Niño events, Zambia typically experiences decreased rainfall, leading to droughts and water scarcity.

2

La Niña

Conversely, La Niña events often bring above-average rainfall to Zambia, resulting in potential flooding and infrastructure damage.

3

Unpredictable Patterns

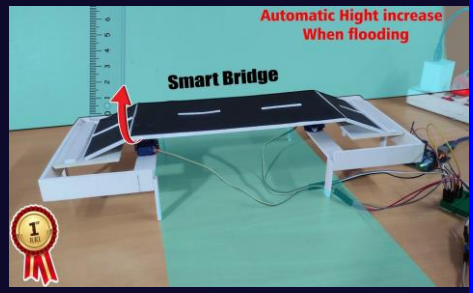
The timing and intensity of ENSO events can vary, making it challenging for Zambia to plan and adapt to the changing rainfall patterns.

The Role of Engineers in Responding to ENSO-Related Risks:

Resilient Infrastructure Design

1 Flood-Resistant

Taking into account disaster risk, begin to think of elevating critical infrastructure and utilizing flood-proof materials to help protect communities from **La Niña** -driven flooding.



2 Drought-Resistant

Design infrastructure, selecting construction materials that can withstand extended periods of elevated temperatures to improve the resilience of Zambian infrastructure, e.g., water storage systems from the impacts of **El Niño** events.

The Role of Engineers in Responding to ENSO-Related Risks: Energy Mix

1

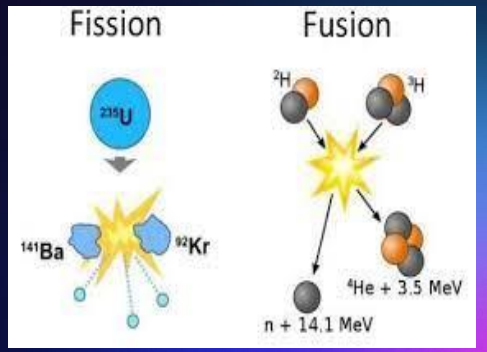
Renewable Energy Integration

Scale-up renewable energy sources, such as solar and wind, engineers can diversify Zambia's energy mix and reduce reliance on hydropower vulnerable to **El Niño** -driven droughts.

2

Nuclear Fusion

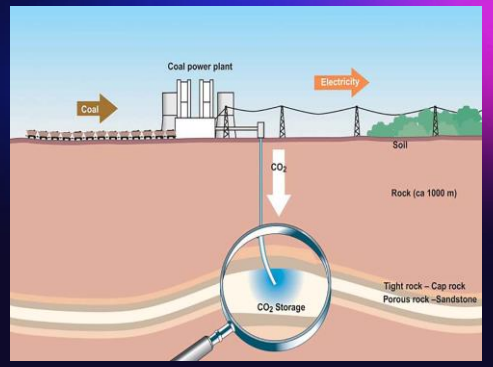
Fusion = two hydrogen atoms fuse to form one helium atom – the process that powers the sun —energy 4 times greater than fission. **Recall Einstein's equation: $E=mc^2$.** Fusion offers a potential long-term energy source: does not produce greenhouse gases or long-lived radioactive waste. The fission of 1kg of uranium or plutonium (coal) 12 tonnes.



3

Coal-fired, plus Carbon Capture & Storage

a) The feedstock coal = desulfurized before burning = stack emissions scrubbed = CO_2 is captured = and excess = injected into the ground.
b) Integrated gasification combined cycle (IGCC) systems = steam, and hot pressurized air /oxygen is reacted with coal = force carbon molecules apart = product mixture, water gas (carbon monoxide and hydrogen), is then cleaned and burned in a gas turbine to produce electricity



the Engineering Institution of Zambia

The Role of Engineers in Responding to ENSO-Related Risks: (Sustainable Water Management)

1

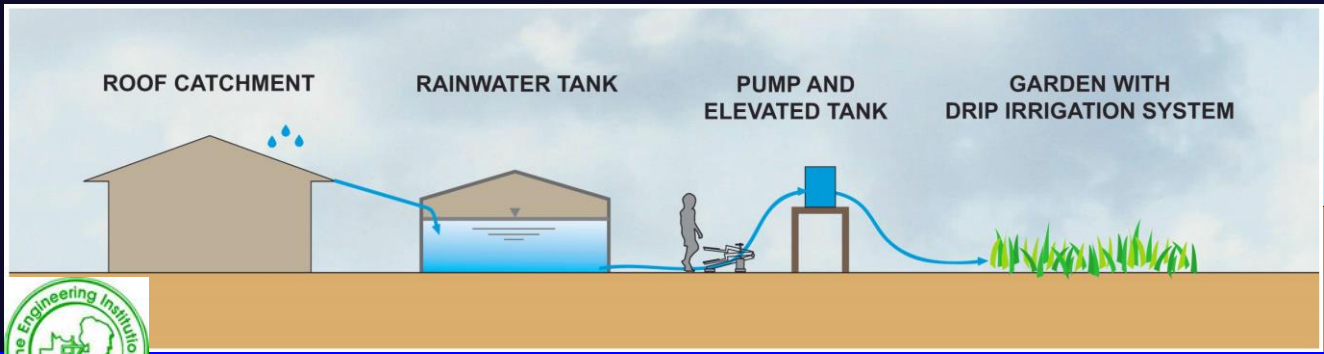
Rainwater Harvesting

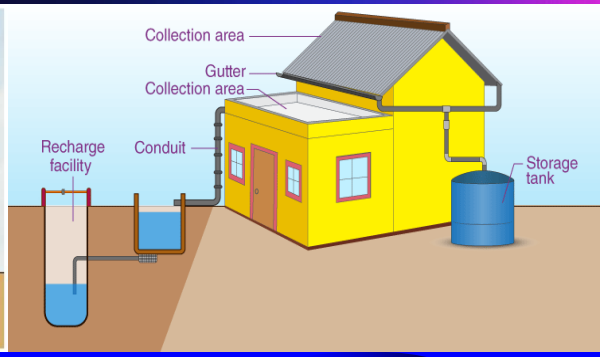
Investing in rainwater harvesting infrastructure can provide communities with a reliable source of water during El Niño-driven droughts.

2

Water Efficient Irrigation

Promoting the adoption of water-efficient irrigation techniques can optimize the use of limited water resources in Zambian agriculture.





The Role of Engineers in Responding to ENSO-Related Risks: Agriculture/Food Security)

1 Combine off-season crop production

El Niño-related droughts disrupt rainfed food-crop production and reduce food security…improve agricultural productivity through, e.g., identification of early-maturing crop varieties.

Soil moisture retention improvement using e.g., biochar. Which has many environmental benefits e.g., soil carbon storage enhancement reducing carbon emissions from the agriculture sector in the long run (Brtnicky et al. 2021).

2 Enhance circular economy

Enhancing agro-forestry. e.g., acacia (faidherbia albida) leaves - known for producing fodder can support livestock during the dry season, and also fertilizes farmlands (decomposition remnant leaves giving off nitrogen) (Teklehaimanot 2004). crop-yield remnants are used as folders for cattle feed, and by-products (cattle manure) are then used as soil conditioners /produce biogas, resulting in closed-loop resource efficiency.

Conclusion and the Future

Engineers	Provide technical expertise and innovative solutions
Policymakers	Develop supportive policies and funding mechanisms
Communities	Share local knowledge and participate in decision-making processes

Effective collaboration among these stakeholders is crucial for developing and implementing comprehensive ENSO adaptation strategies in Zambia.

Thanks very much!

Merci beaucoup!

Dziękuję bardzo!

Огромное спасибо!

非常感谢！