El Niño and La Niña
and the "El Niño Southern Oscillation" - ENSO
And Current Global Warming

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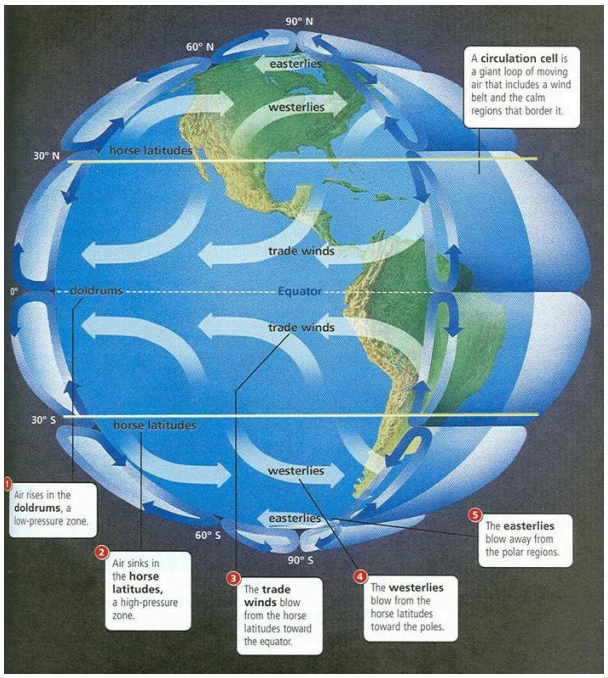
El Niño and La Niña

Recently, the subject of El Niño and La Niña came up. These systems are still being studied, but they have global impacts, including temperatures. Since they are hard to predict, it is safe to say they are poorly understood.

Let's walk through the general features, step-by-step:

Remember the **Atmospheric Cells**, specifically the Hadley Cell caused by the heated, moist air rising at the equator, then coming back to the surface around 30^0 N and S, with it now drier air picking up moisture as it heads back along the surface to the equator. Combining that effect with Global Rotation produces **the Trade Winds, generally moving from East to West around the Equator.**



https://socratic.org/questions/5a5b8f5f7c01493711053688

In most years, the Trade Winds drive the **Surface Ocean Currents to the eastern side** of the Pacific Ocean. So, warmer surface water piles up near Asia and Australia.

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Approximate "Cheat Sheet":

1 meter → 3 feet **1 degree Celsius (^{0}C)** → 2 degree Fahrenheit (^{0}F)
ppm = parts per million **CO_2** = Carbon Dioxide
1 tonne = 1000 kilograms = 2205 pounds **1 gigatonne (1 Gt)** = 1 billion tonnes
1 trillion tonnes (1Tt) = 1000 gigatons

El Niño and La Niña

[At this point, I'm going to use materials straight from: https://earthhow.com/el-nino-la-nina/, which was unusually well done, particularly the graphics. My notes will be in bracketed italics].

"**The El Niño and La Niña** phenomena are part of a 3 phase cycle that occurs in the Pacific Ocean."

- **EL NINO:** El Niño is the **warming phase of the waters in the eastern Pacific,** off the coast of South America.
- **LA NINA:** Then, La Niña is the **cooling phase** off the coasts of Central and South America.
- **Normal Conditions:** what persists most of the time, reflecting **normal trade winds**

Both phenomena disrupt weather and temperature around the globe. For example, they unpredictably create:

- Heat waves
- Floods
- Droughts

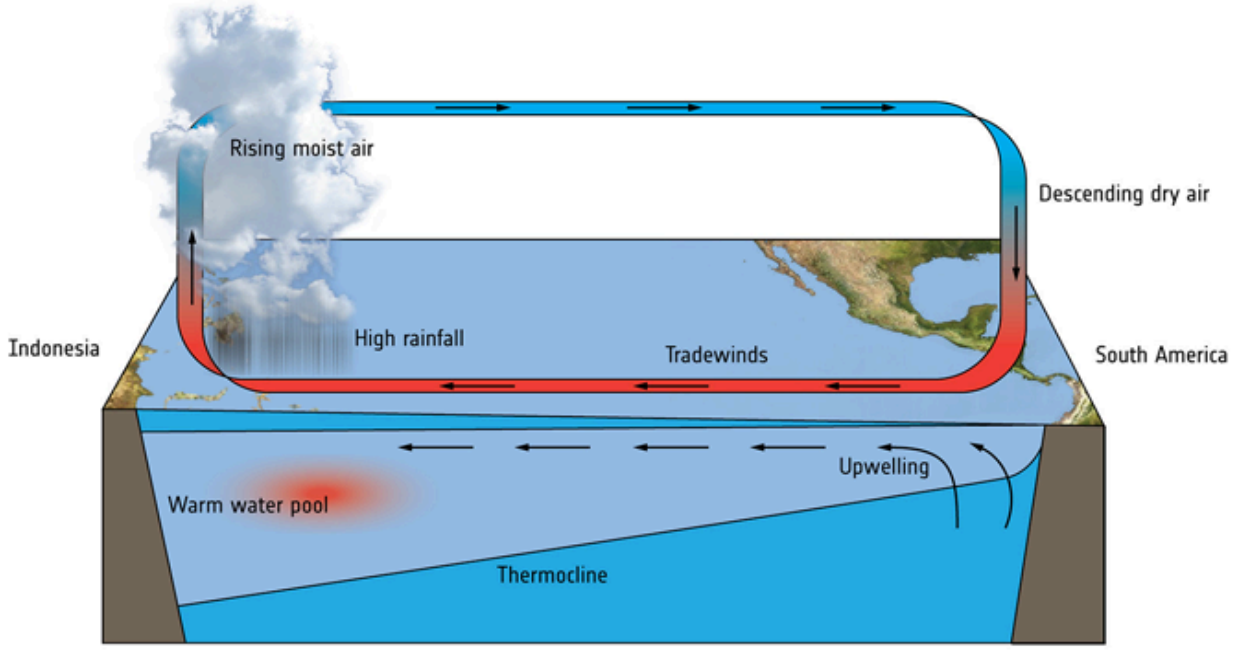
El Niño and La Niña peak around Christmas time and can last 9 months or longer. Then, it **repeats again every 3-5 years or so**. But how does El Niño work? And what causes El Niño? Let's examine the El Niño phenomenon.

This cycling of the Pacific conditions is often termed the

El Niño Southern Oscillation or ENSO.

Normal Conditions

El Niño takes place in the Pacific Ocean near the equator. In normal conditions, Trade Winds blow from east to west. These winds push warm water like a conveyor belt to the coast of Asia and Australia. Then, warm water pools in the west of the Pacific Ocean. This causes the **thermocline** (top-to-bottom ocean temperature gradient) to deepen *[there]*.



Normal conditions

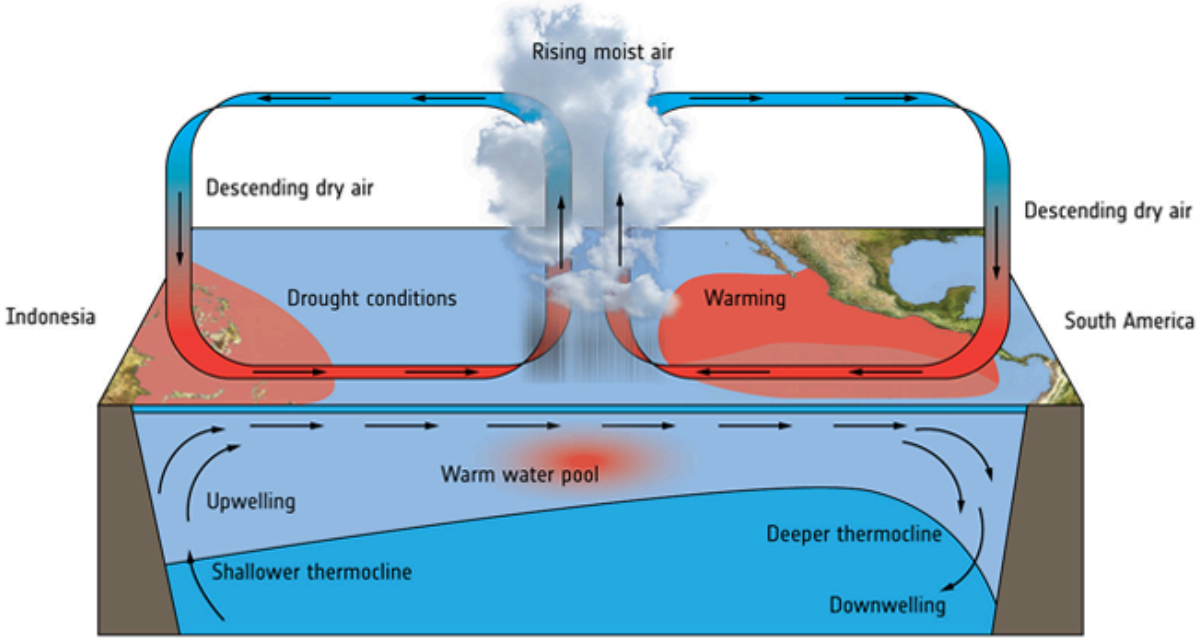
But **along the coast of the Americas, cold water from deeper down in the ocean replaces the warm surface water** that is transported to the west. This process of deep, cold water rising to the surface is called **"upwelling"**. So in normal conditions, there's a big temperature difference from east to west in the Pacific Ocean.

In the western part of the Pacific Ocean, the warmer water adds extra heat to the air. Then, this causes the **air to rise generating clouds and rainfall** in a self-feeding cycle. First, we have warm moist air rising in the west. Secondly, **dry cool air descends on the eastern side of the Pacific Ocean**. This type of atmospheric circulation continues until El Niño begins.

[Please notice that the circulation of the atmosphere in the above graphic is east-west, so is not the Hadley Cell circulation, which is north-south - it impacts the Hadley Cell circulation. We'll be finding that the "orderly" climate-driving cells are an important starting point, but real weather is a constant re-combining of all sorts of temperatures, pressures, winds, etc.!]

El Niño

Every 3-5 or so years, El Niño is triggered by a weakening of west-blowing Trade Winds. As winds weaken, it results in less warm water to the west. Consequently, there is also **less cold upwelling water off the coast of the Americas**.



El Niño conditions

So, there's less push of warm surface water to the west. On top of that, there's less upwelling on the eastern side. **As a result, warm water piles up centrally in the Pacific Ocean disrupting the normal temperature balance between the eastern and western Pacific**.

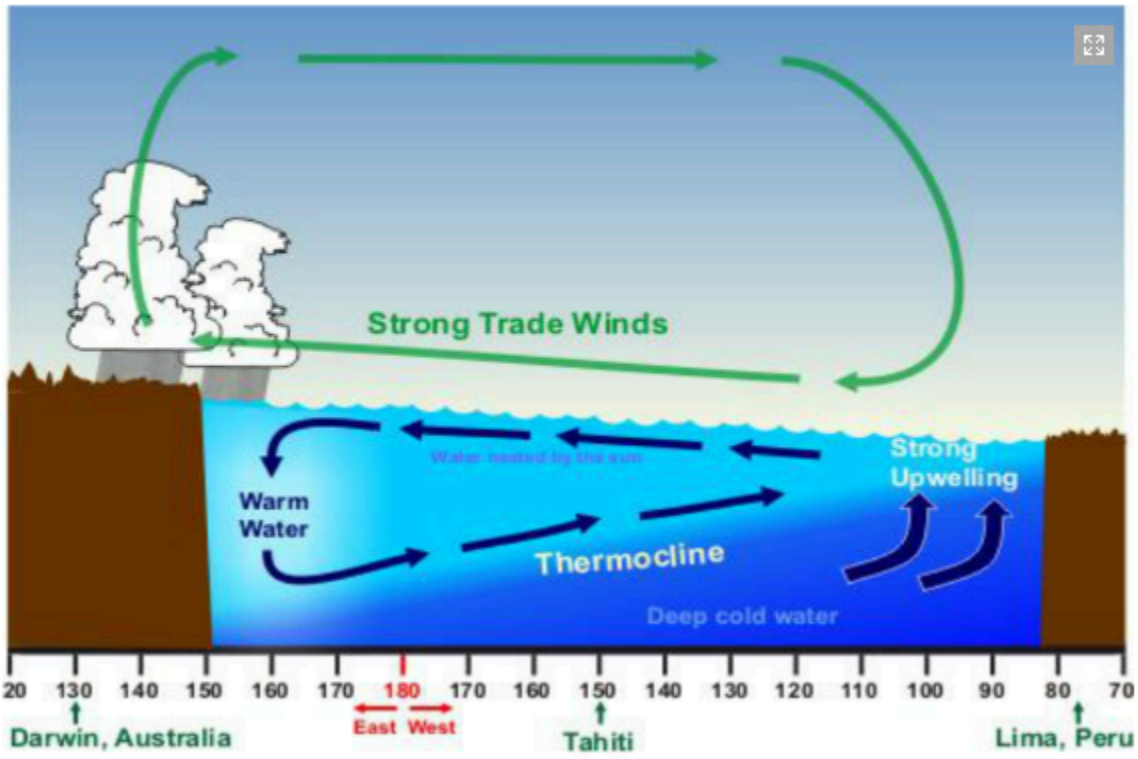
During El Niño, the increased water temperature drives rainfall. If you have concentrations of heat, it forms pressure systems that build storms. *[As we've seen in earlier discussions, warm, moist air rises leaving a low pressure area below, cools at high altitudes, then dumps rain down.]* This is why the **equatorial Pacific has increased rainfall and winds**.

Then, these conditions **impact global weather conditions** in other regions around the world.

La Niña

After El Niño reverses back to normal conditions, it can dip into its counterpart La Niña. La Niña is basically El Niño in reverse. ***[It operates like a "normal" circulation - but on steroids!]***

Instead of a weakening of Trade Winds, La Niña experiences a **strengthening in equatorial air circulation.** La Niña pushes warm water even further west. Then, it **increases the upwelling of colder water in the eastern Pacific** decreasing temperatures there.



https://pirca.org/2016/04/07/what-happens-during-el-nino-and-la-nina-events/#prettyPhoto/0/

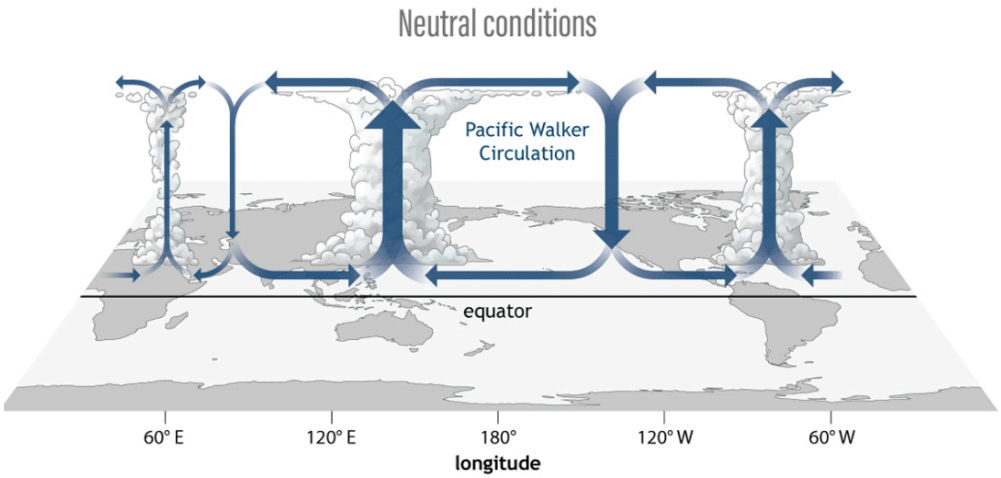
Similar to El Niño, La Niña can have a **major impact on global weather** as well.

La Niña tends to have the **reverse effects of El Niño**. For example, you get drought conditions in countries near the eastern Pacific because the cooler water produces less rain.

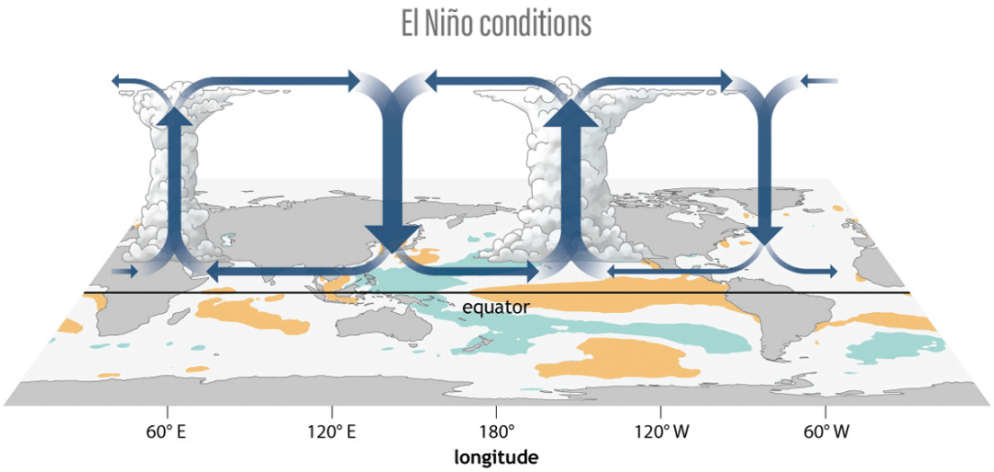
El Niño and La Niña

Below is a depiction which ties ENSO to large regions of the globe

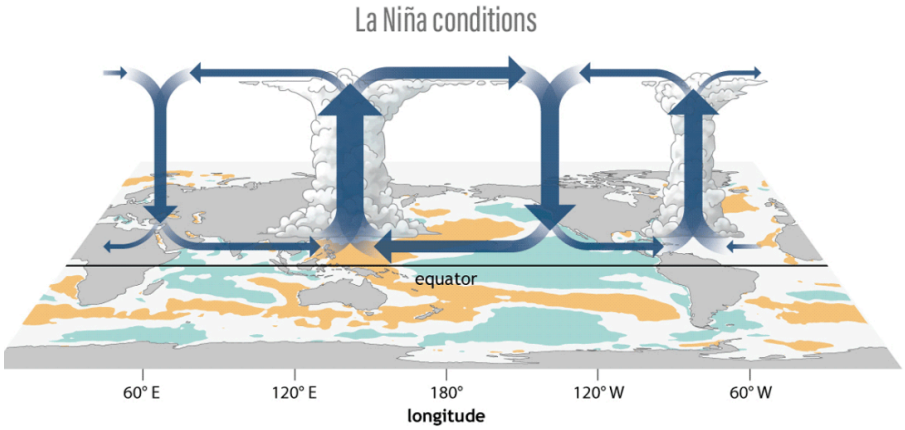
https://www.climate.gov/news-features/blogs/what-we-talk-about-when-we-talk-about-jet-stream-and-el-nino



[Neutral = Normal: Note that the surface water above is a neutral color to show average]

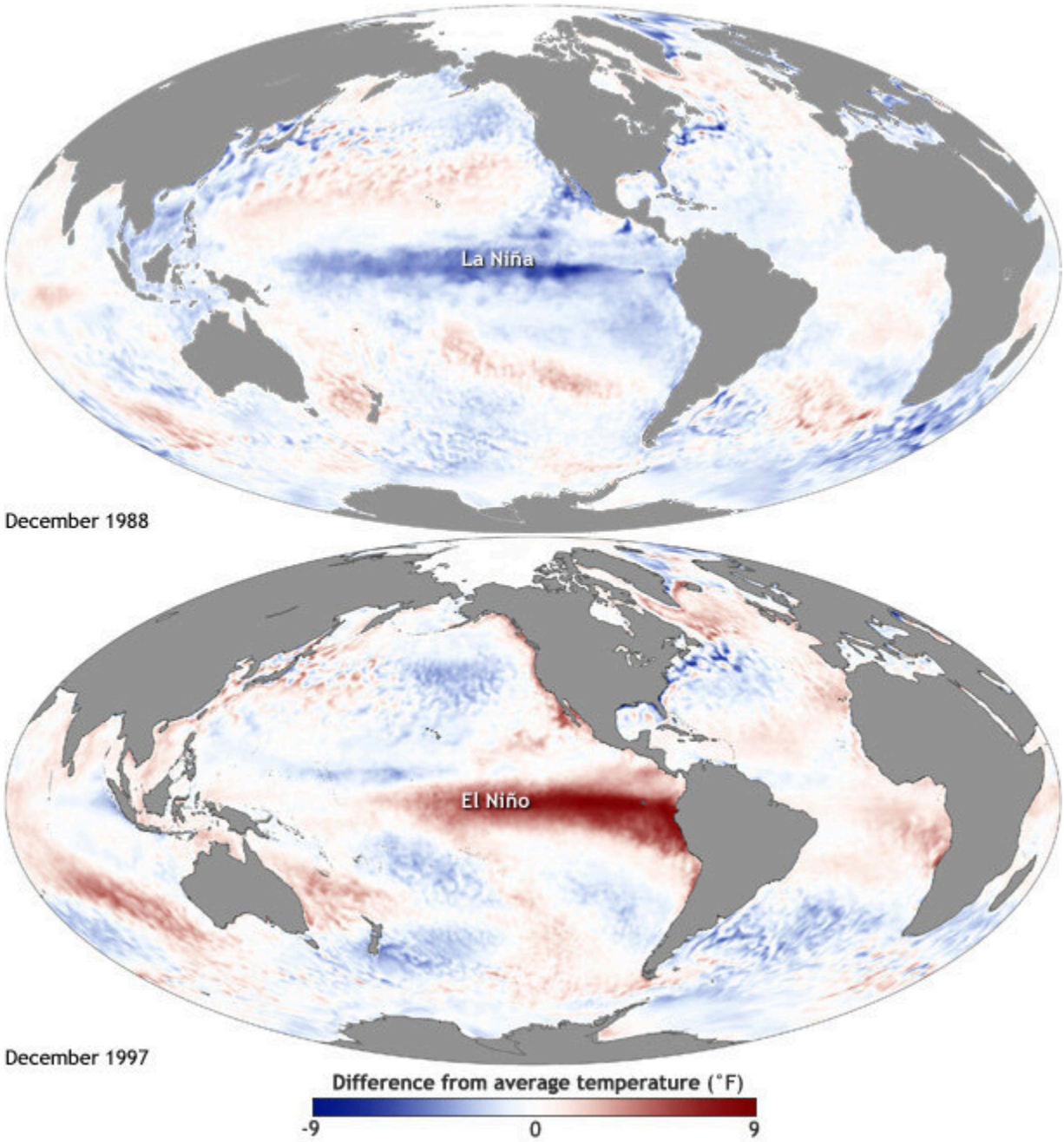


[El Nino & La Nina: Surface water coloration indicates a change from the "Normal"]

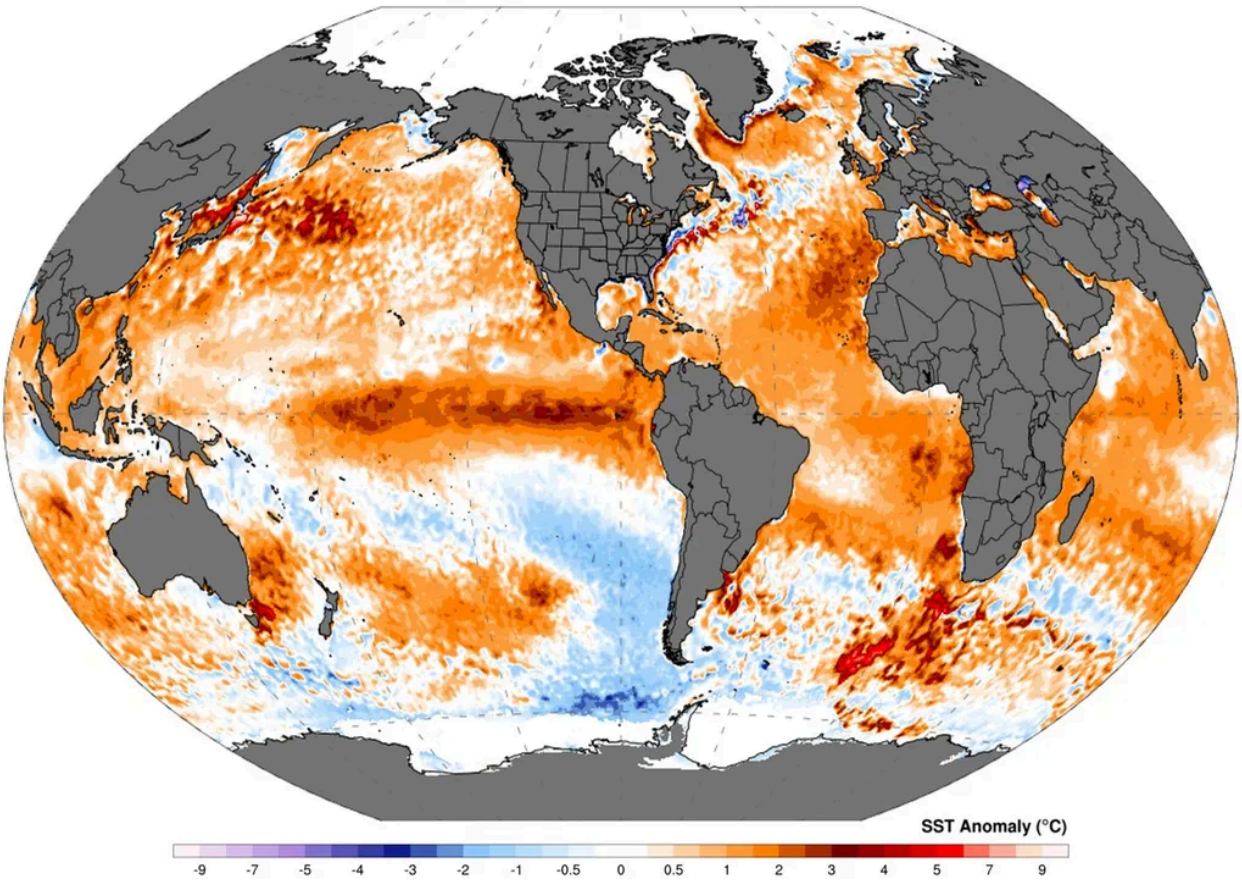


El Niño and La Niña

Here's a view of a specific cycle from 1997 - 1998



And this is from LAST MONTH (we're right in the middle of an El Nino now!)



Map of sea surface temperature anomaly for December 17, 2023. Source: Climate Reanalyzer.

How Does El Niño Affect Weather?

As part of the big picture, El Niño releases vast amounts of energy pushing up global temperatures. This is why El Niño years are often the warmest on record.

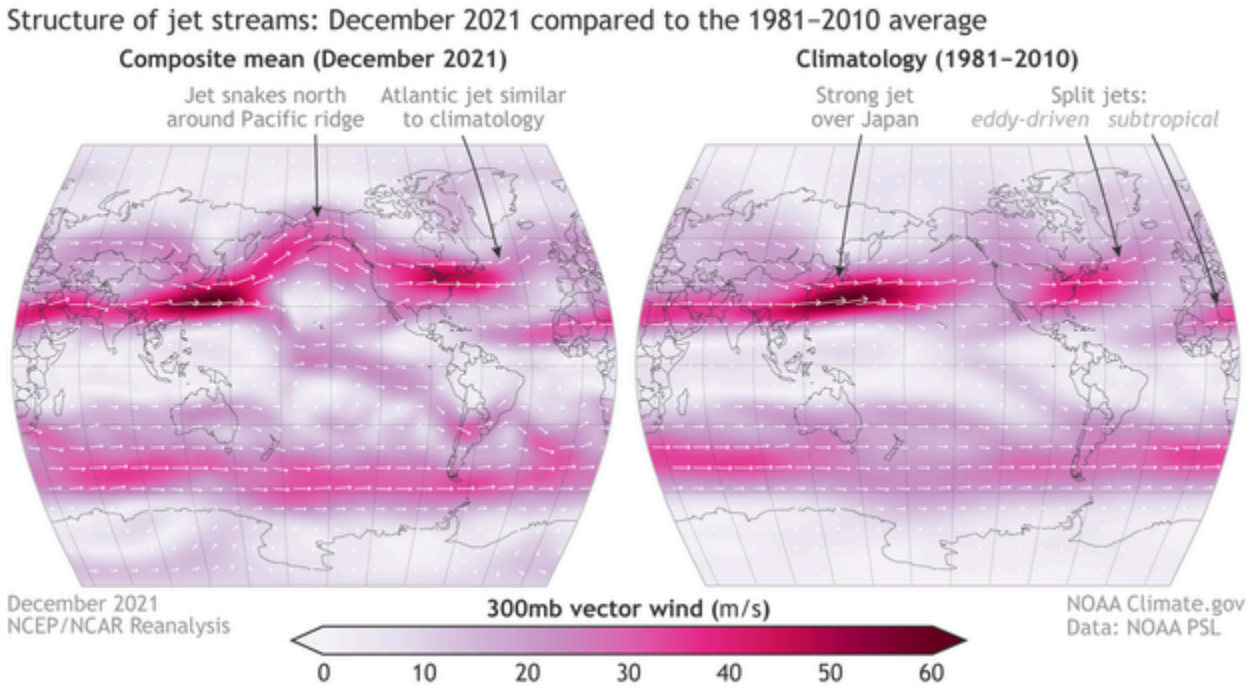
The main weather impacts from El Niño occur in the tropics. For example, here are some of the effects worldwide:

- FLOODING: Peru often experiences flooding.
- DROUGHT: India, Indonesia, and Brazil have drought conditions.

But El Niño can drive heatwaves, floods, and droughts outside the tropics too. It can affect virtually everywhere in the world directly. If not through the weather, it will at least have socioeconomic impacts.

Let's take a slightly deeper look at how global effects occur:

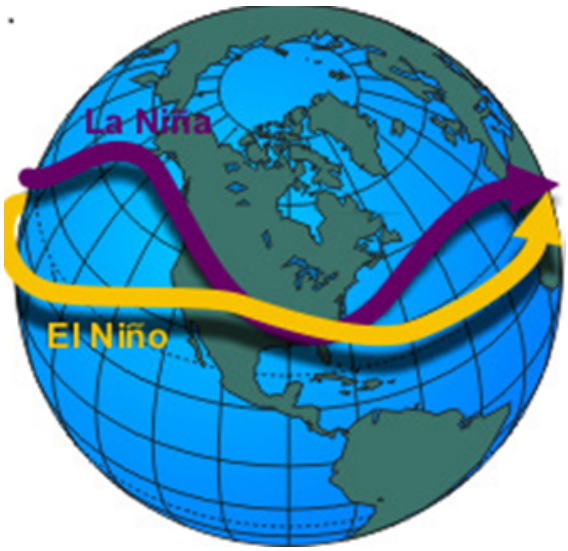
But first, no matter what we said or implied in earlier studies, the jet streams are not those simple bands around the globe. Because of seasons, local weather, pressure intensities, topography, etc., they move around, merge, break apart, and respond to big changes, like ENSO. **Here's a specific month (December, 2021) compared to the 30 year average climatology (1981-2010).**

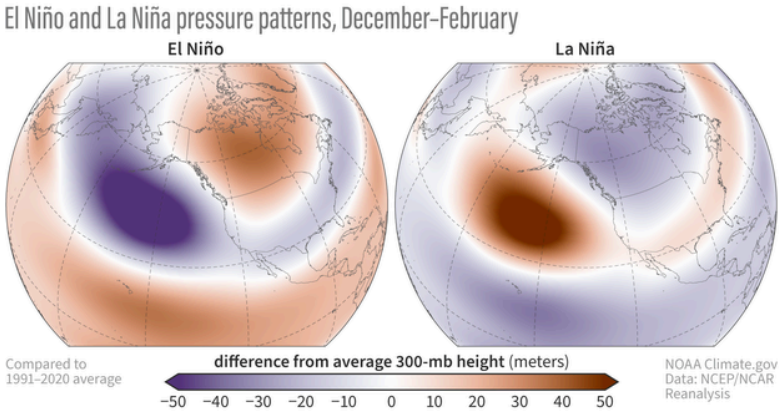


https://www.climate.gov/news-features/blogs/enso/what-jet-stream#:~:text=Firstly%20%2C%20the%20jet%20acts%20to,way%20down%20to%20the%20surface.

El Niño and La Niña

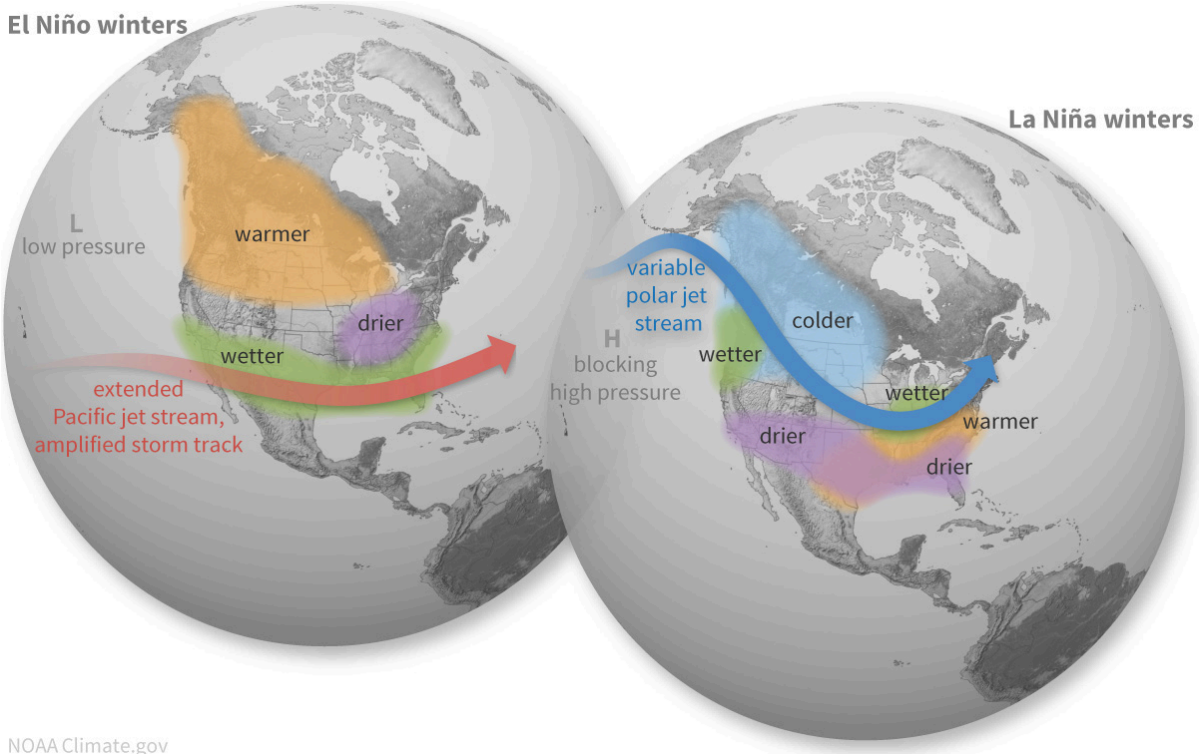
Here's a simplification of the subtropical jet stream as it adjusts to the ENSO conditions:





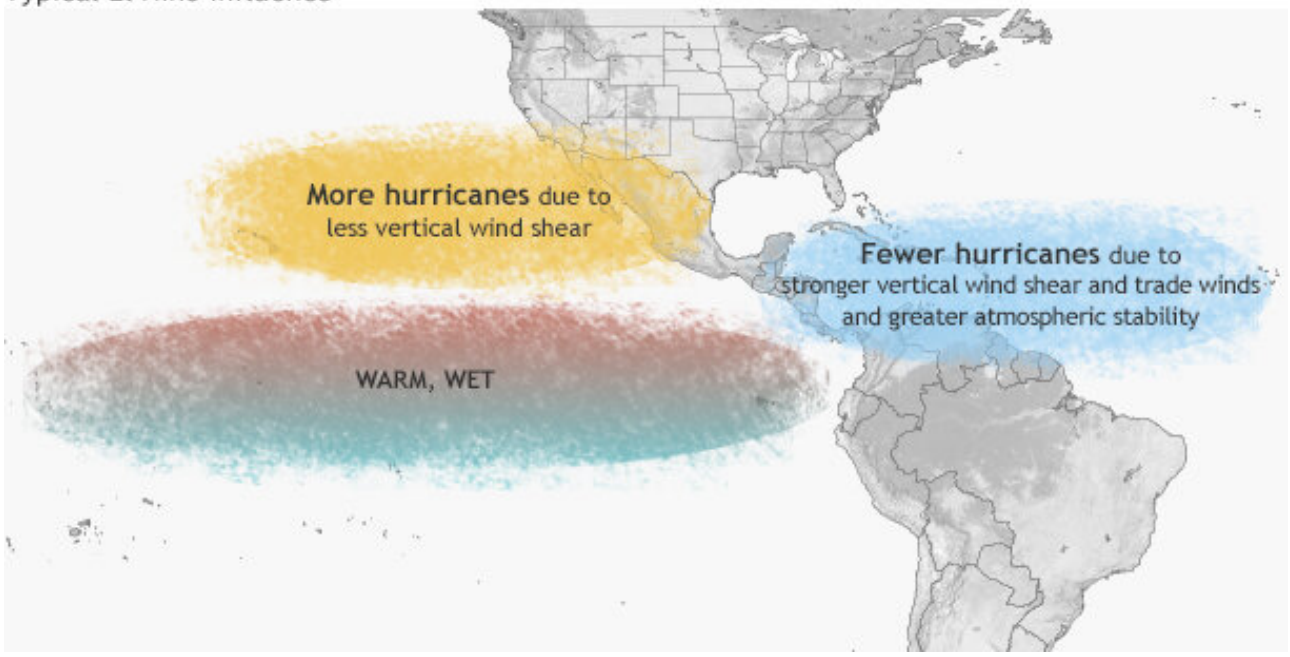
Winter atmospheric pressure patterns during El Niño and La Niña, shown as the 300 mb geopotential height difference from the long-term average, where long-term is 1991–2020. All El Niño and La Niña winters from 1950–2023 are averaged here. The pressure south of Alaska is lower than average during El Niño and higher than average during La Niña. Figure by climate.gov based on data analysis of NCEP/NCAR Reanalysis by Michelle L'Heureux.

These bring changes to our weather. Again, these are trends, not necessarily specific to a particular ENSO:

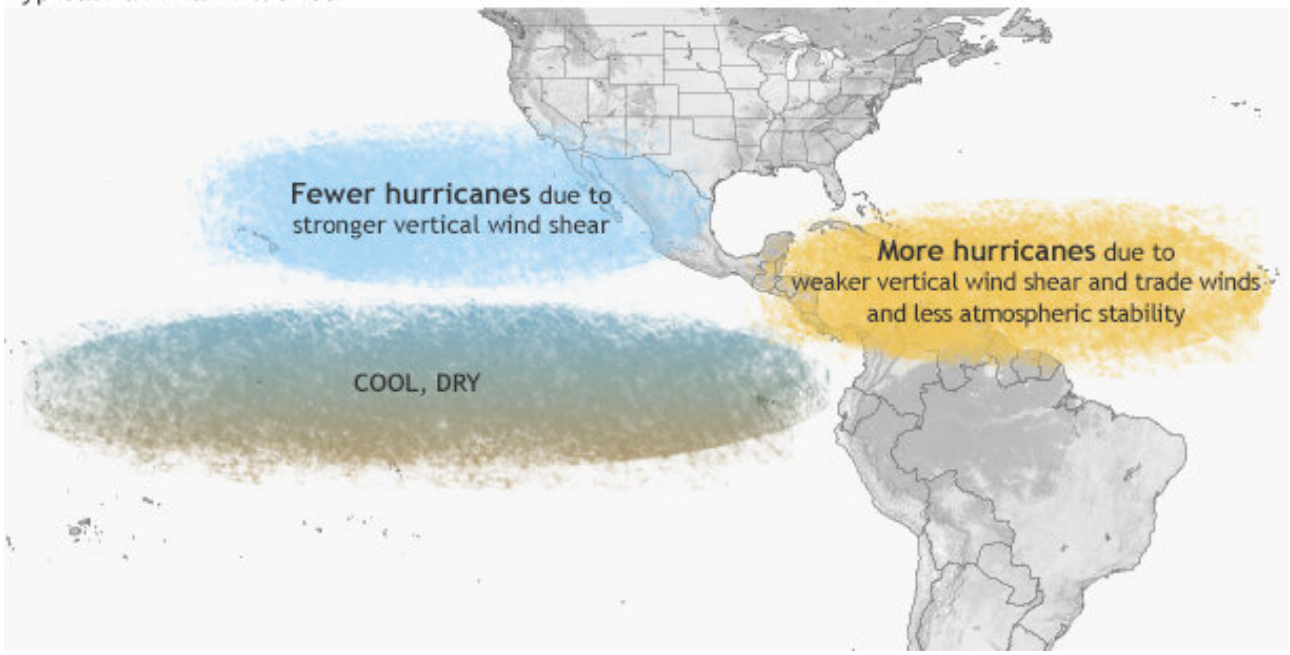


El Niño and La Niña

Typical El Niño influence

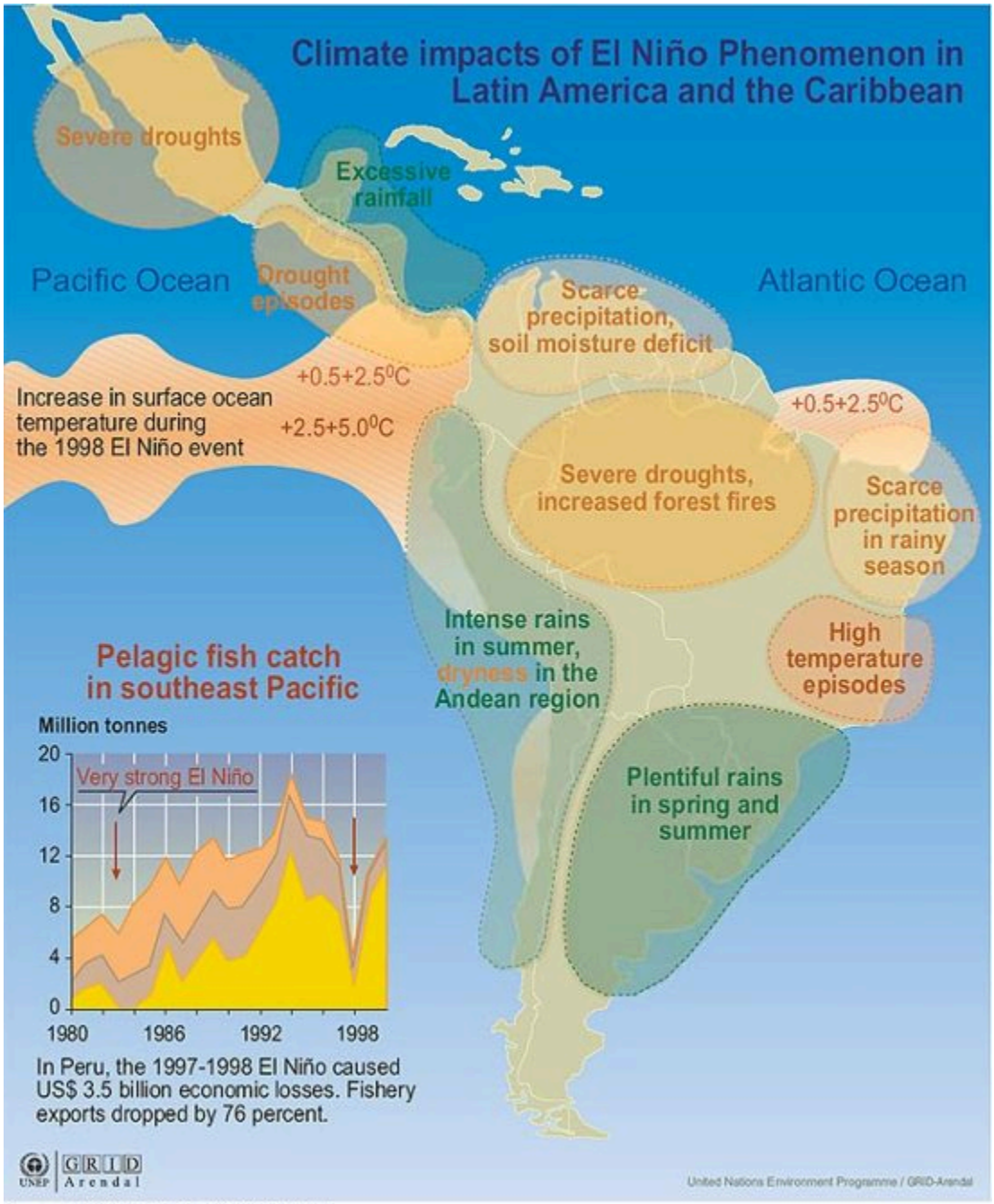


Typical La Niña influence



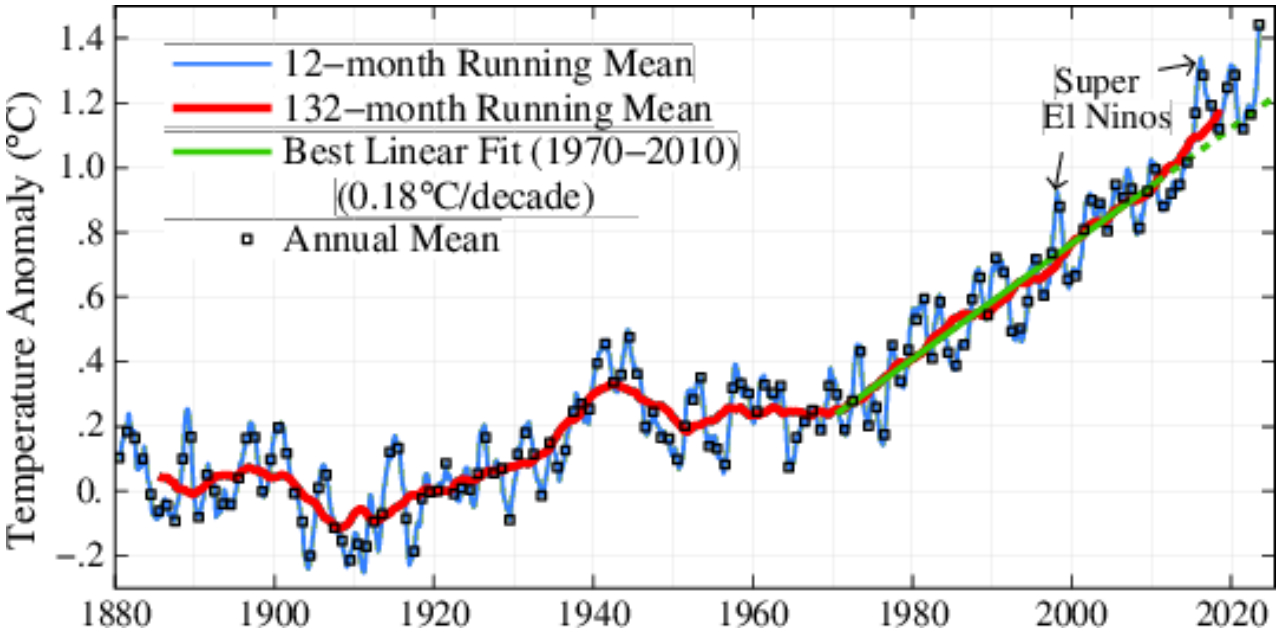
El Niño and La Niña

And, to our South, here are some impacts in terms of changes from the average climates:



Sources: IPCC 2001, FAO 2002,UNEP 2003

El Nino in the context of Global Temperatures



We have seen this graph of the global temperature rise since the industrial revolution many times. Here we see how the strongest El Ninos simply add to the story.

*** * * * * * Annual Mean Temperature Ranking (Top 10) * * * * * ***

The top 10 warmest years were all in the past 10 years (2014-2023)

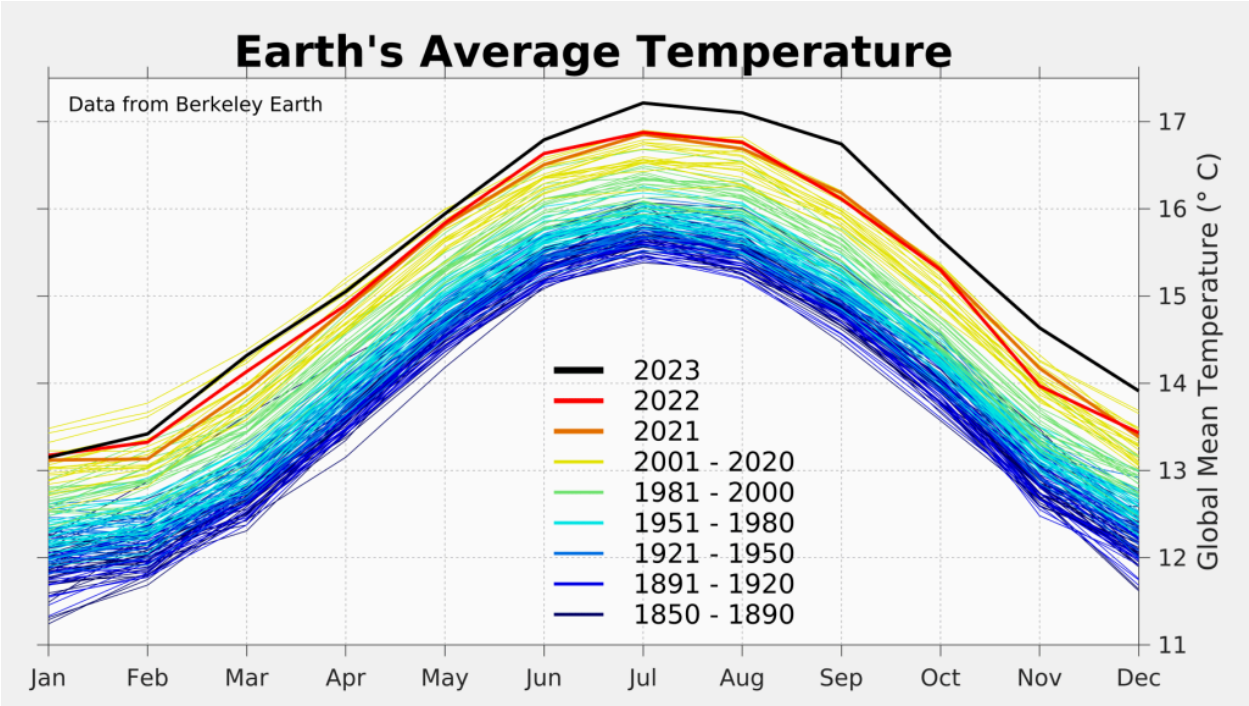
So, how does the ENSO cycle tie in specifically?

El Niño and La Niña

In 2023, La Nina was pretty much over by February. El Nino was strongly emerging by May of 2023.

Every month in 2023 was at least 1.2 °C (2.2 °F) warmer than the corresponding 1850 to 1900 monthly average.

- 2023 started with temperatures relatively similar to those from 2021 and 2022.
- **However, as La Niña dissipated, the patterns started to diverge with the new records becoming more extreme in the second half of the year alongside a growing El Niño event.**
- The last 7 months of 2023 all provided new monthly records. **July was also the month with the warmest absolute Earth-average temperature ever measured**, while September provided the largest monthly temperature anomaly on record.

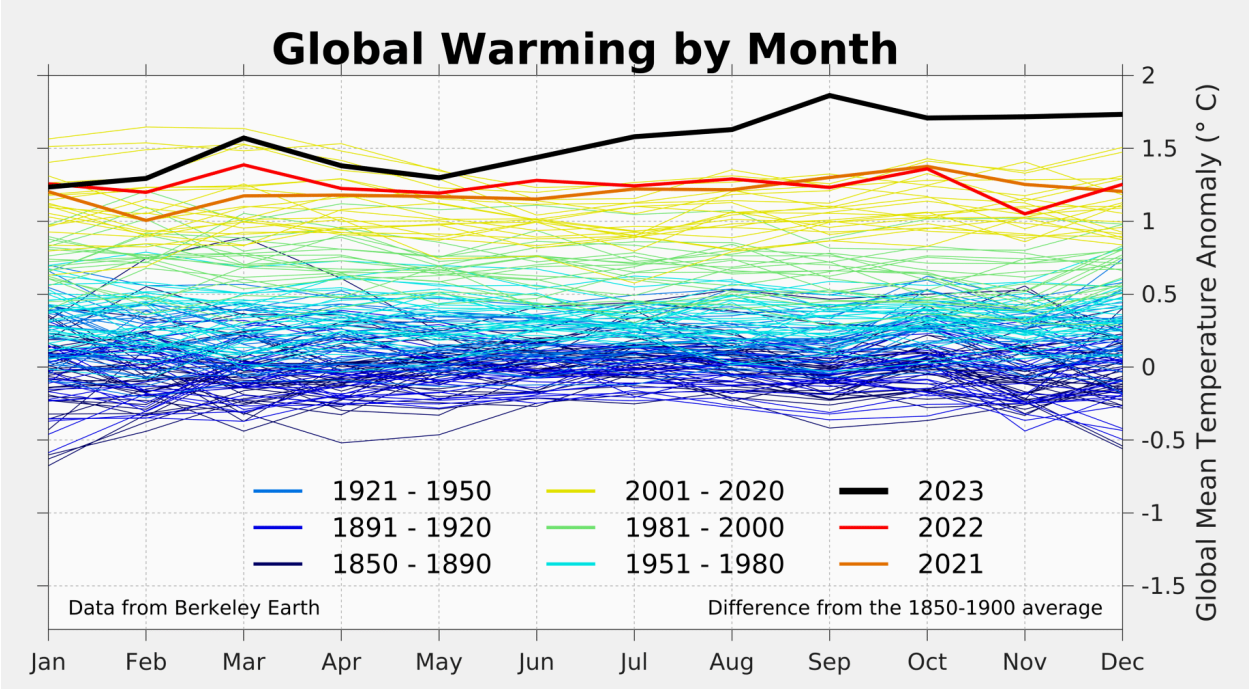


The September anomaly was particularly surprising as September is traditionally a time of the year with lower year-to-year variability. No previous year has seen a deviation in September even remotely similar to what was observed in 2023.

El Niño and La Niña

So, was this El Nino responsible for the incredible jump in global warming?

This is a “hotly” debated subject; another parameter which could well be relevant is a substantial recent reduction in aerosols being emitted by ships because of pollution concerns.

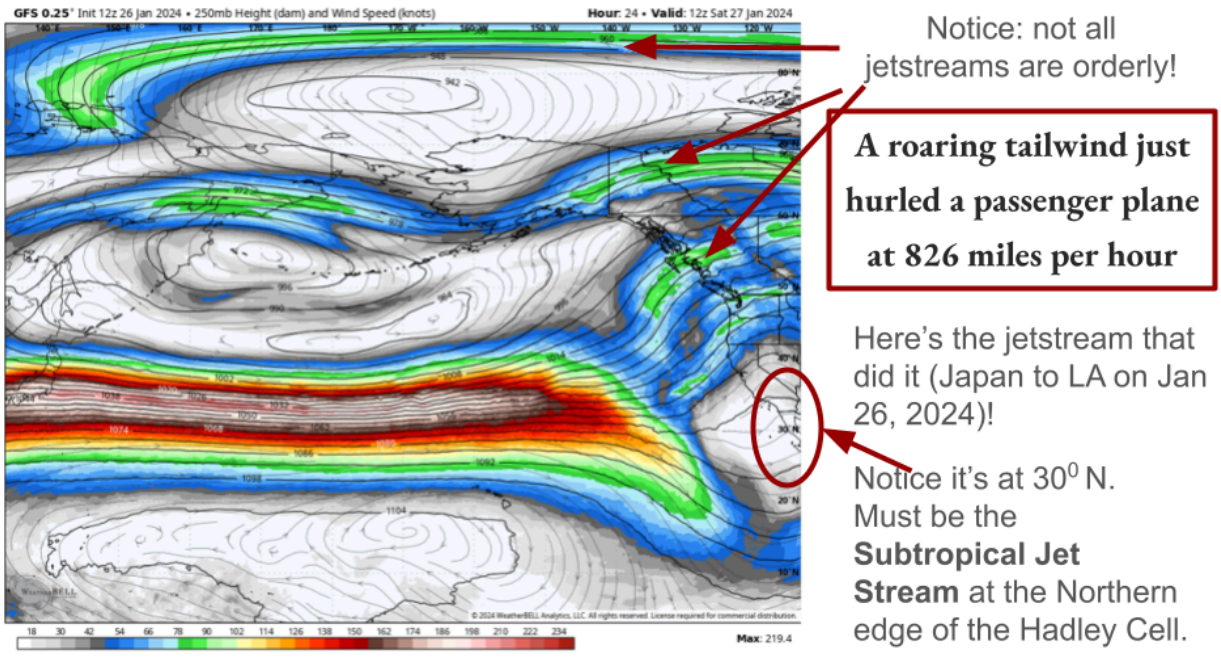


BONUS !

A roaring tailwind just hurled a passenger plane at 826 miles per hour

An exceptional jet stream boosted a China Airlines flight over the Pacific

What's this all about ? The very strong El Niño, which we are now in the middle of, is making the mid-Pacific hotter than usual. Being winter, this drives up the temperature difference between the equator and the cold, dark North Pole region. This strengthens the flow in the top of the Hadley Cell, strengthening and straightening the sub-polar jet stream in turn.



Structure of the Northern Hemisphere jet streams in December 2021 compared to the climatology (average from 1981-2010). Display is showing the wind vectors and strength at the 300mb level in the atmosphere. Figure by NOAA Climate.gov using NOAA ESRL/PSD data.