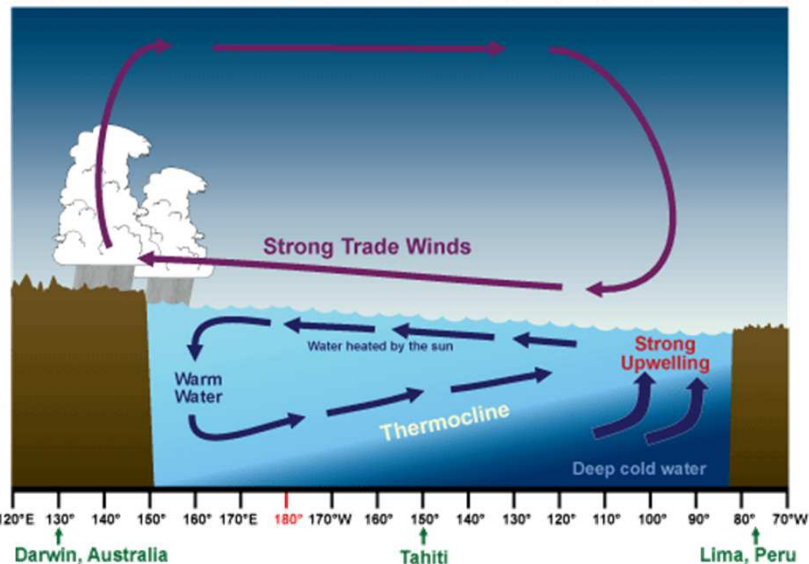
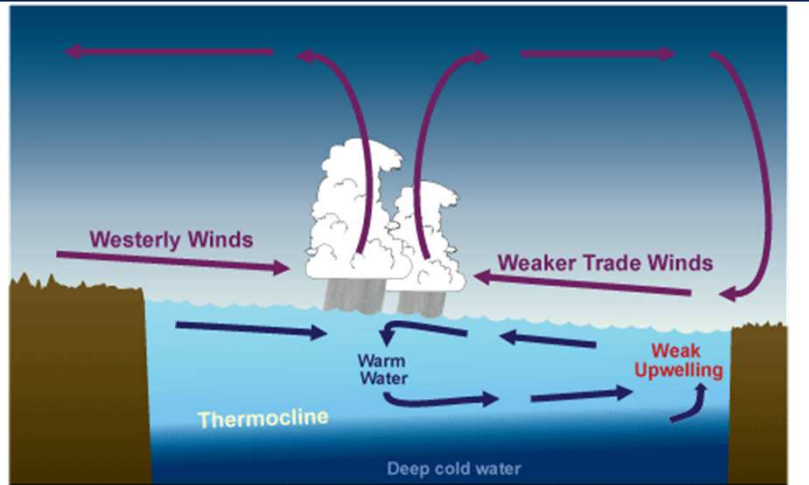


The tropical Pacific as key to global climate variability and change

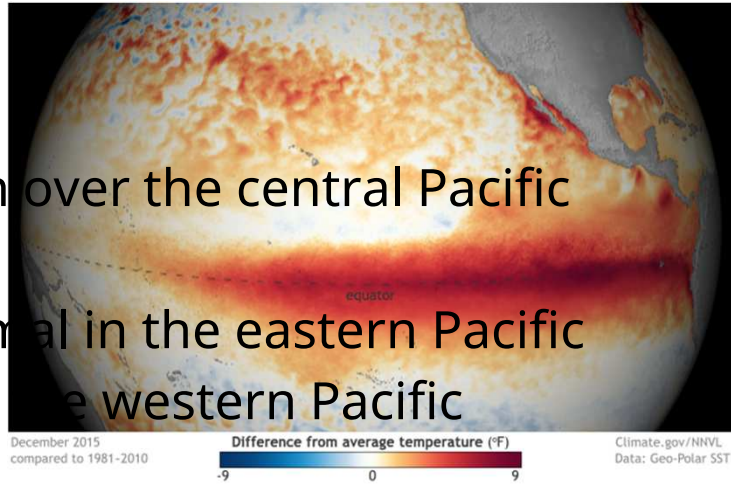
Yu Kosaka
RCAST, The University of Tokyo

The tropical Pacific: Home to El Niño and La Niña



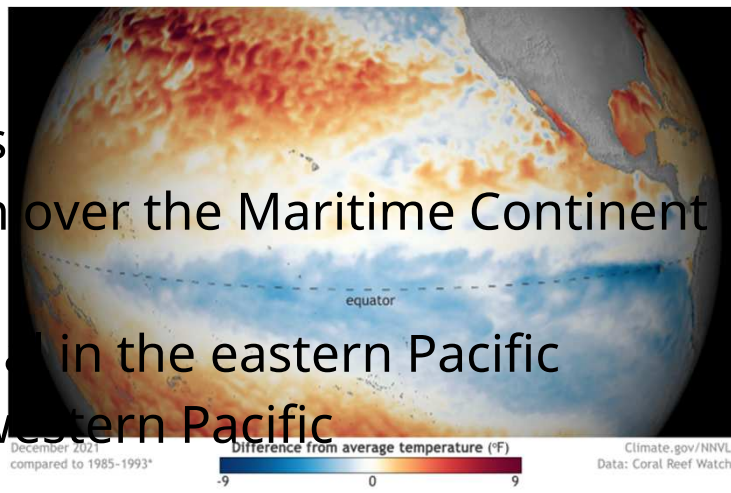
El Niño

- Weaker trade winds
- Enhanced convection over the central Pacific
- Weakened upwelling
 - Warmer than normal in the eastern Pacific
- Sea level decrease in the western Pacific



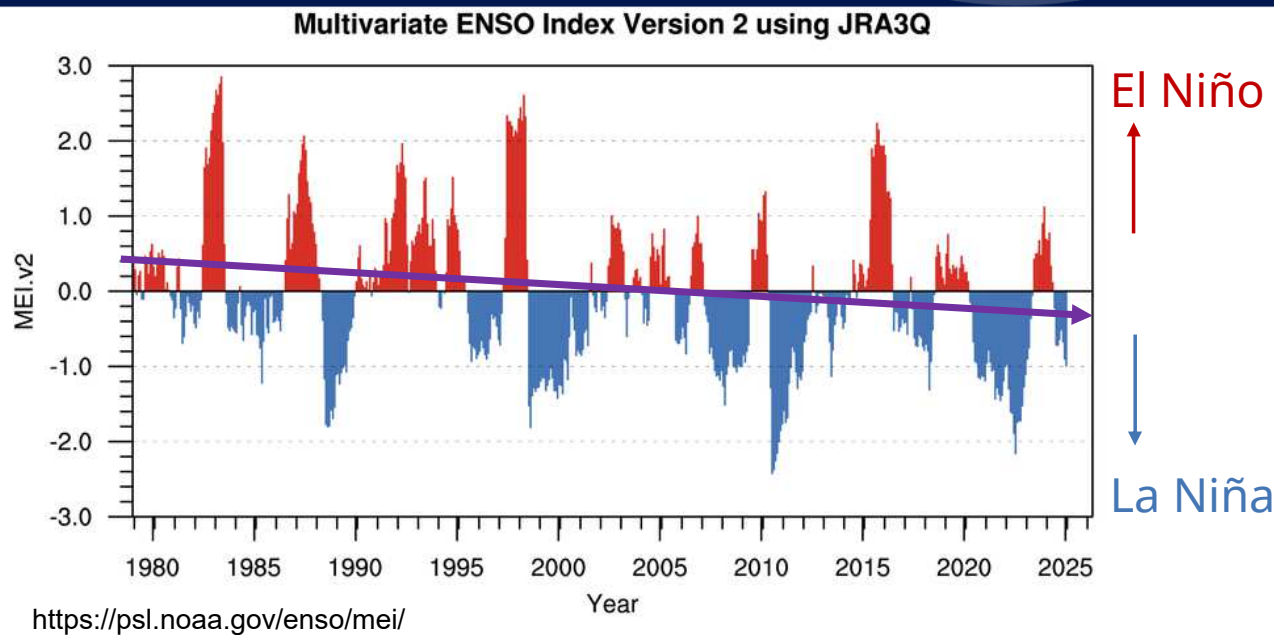
La Niña

- Stronger trade winds
- Enhanced convection over the Maritime Continent
- Enhanced upwelling
 - Colder than normal in the eastern Pacific
- Sea level rise in the western Pacific



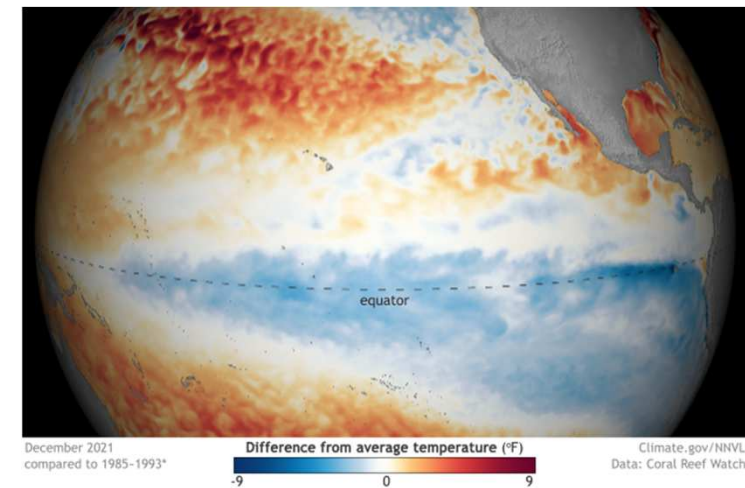
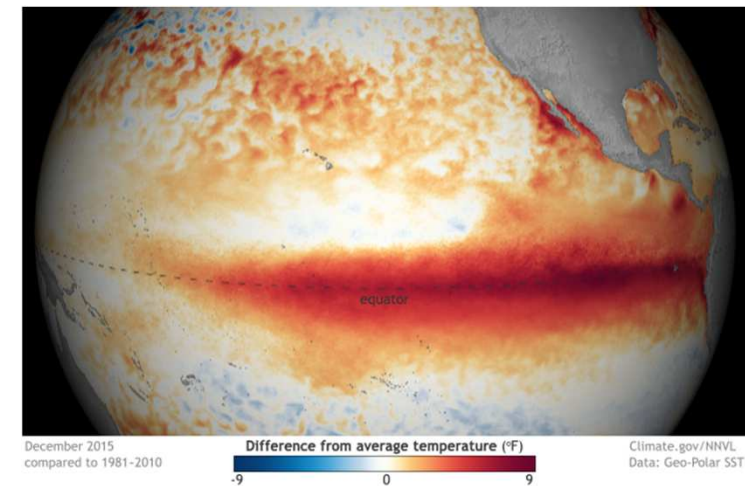
<https://www.noaa.gov/jetstream/tropical/enso/enso-patterns>

The El Niño-Southern Oscillation (ENSO)



El Niño-Southern Oscillation (ENSO)

- (Basically) natural variability
- Organizes variations in **sea surface temperature, winds, precipitation pattern, east-west sea level contrast, tropical cyclone activity**, etc.

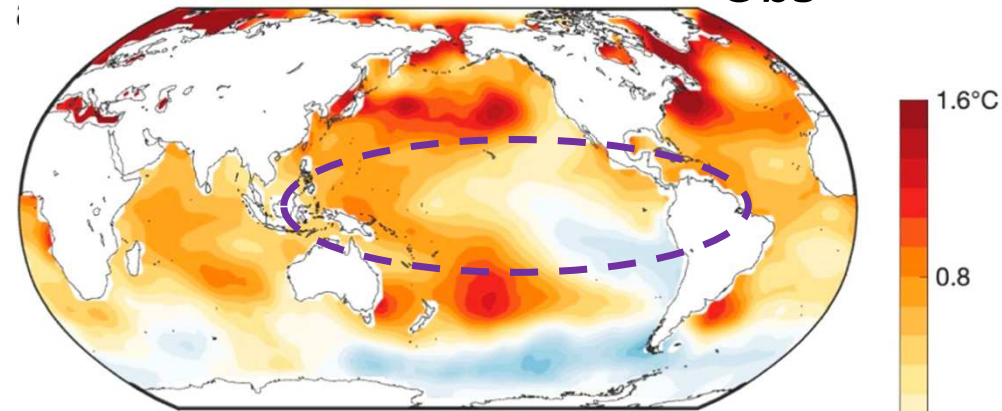


<https://www.climate.gov/maps-data/data-snapshots/data-source/sst-enso-region-monthly-difference-average>

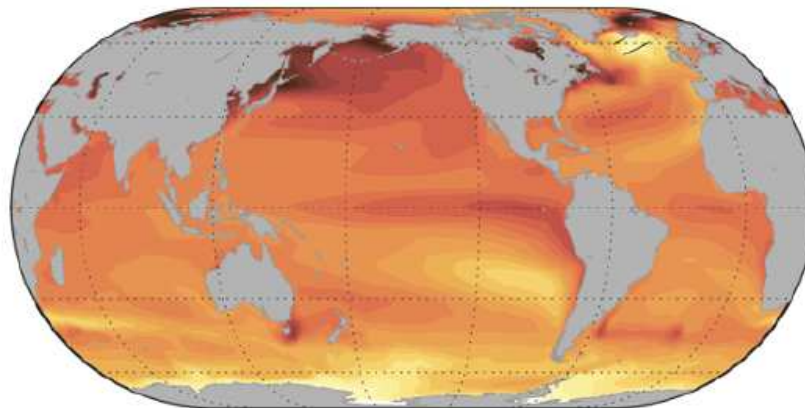
Spatial pattern of surface temperature change

- **Observed change** over the satellite era (since around 1980): "*La Niña-like*"
- **Model-simulated response to forcing** over the same period: "*El Niño-like*"
- Simulated future change is similar to the latter

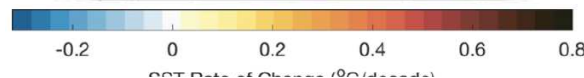
ERSSTv5 SST Trend (1979-2020) Obs



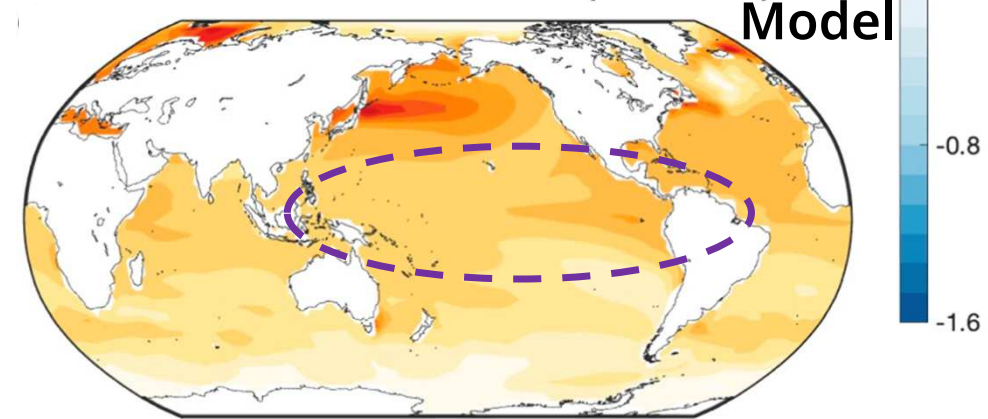
SSP5-8.5 CMIP Change Rate (2005-2100)



IPCC AR6WG1



Multi-Model-Mean SST Trend (1979-2020)



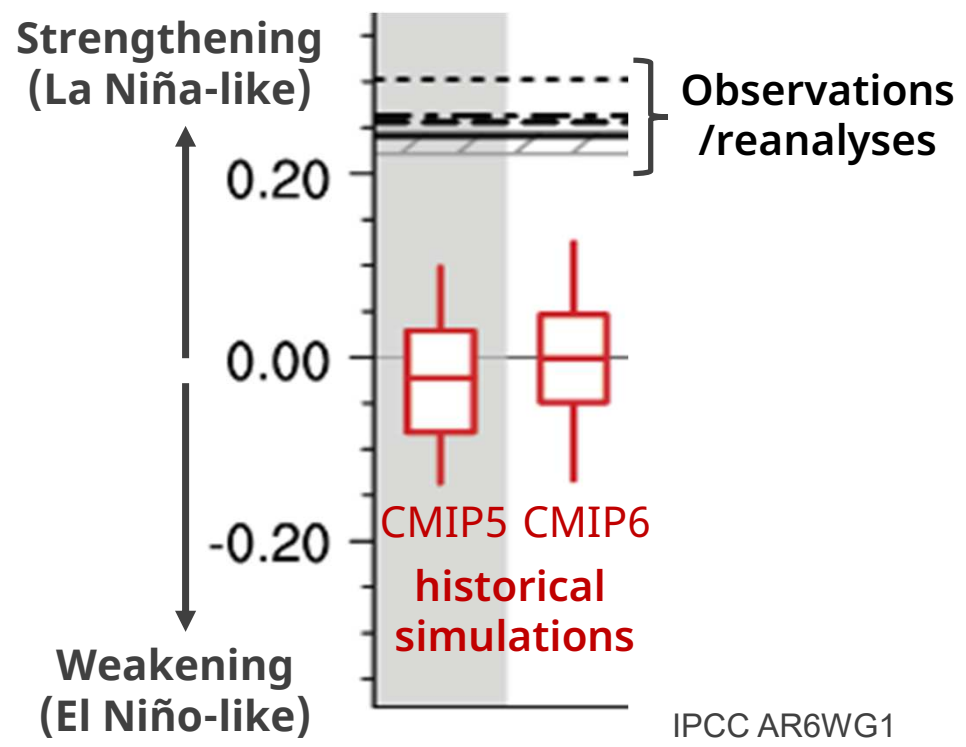
Model

Wills et al. (2022)

The Pacific Walker circulation strengthening

The Pacific Walker circulation: The atmospheric counterpart of ENSO

1980-2014 trend of Pacific Walker circulation strength

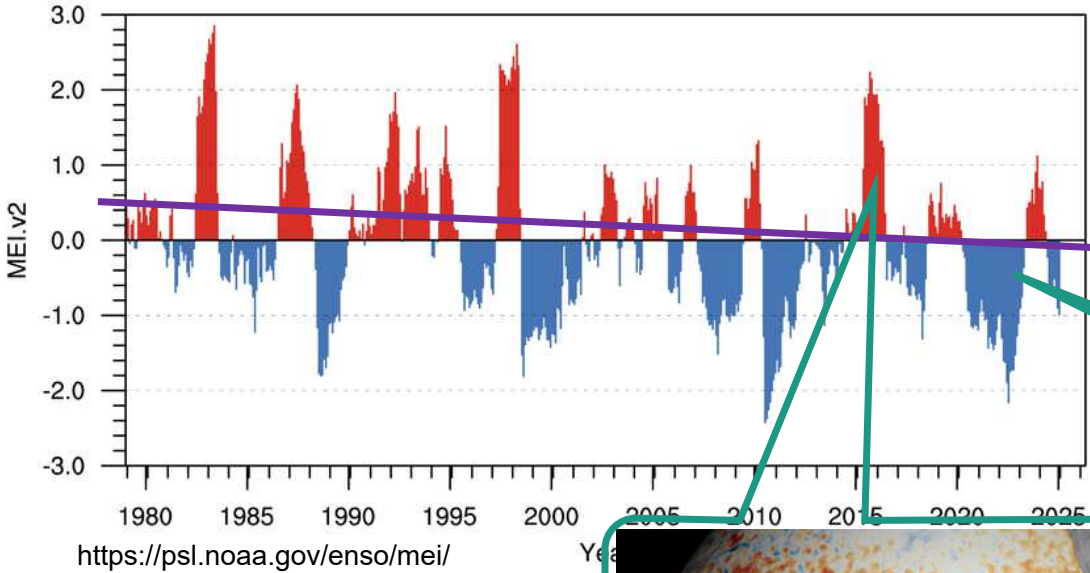


The causes of the observed strengthening of the Pacific Walker circulation since the 1980s are not well understood, and the observed strengthening trend is outside the range of trends simulated in the coupled models (IPCC AR6WG1)

Limiting confidence on the projected *El Niño-like* climate change

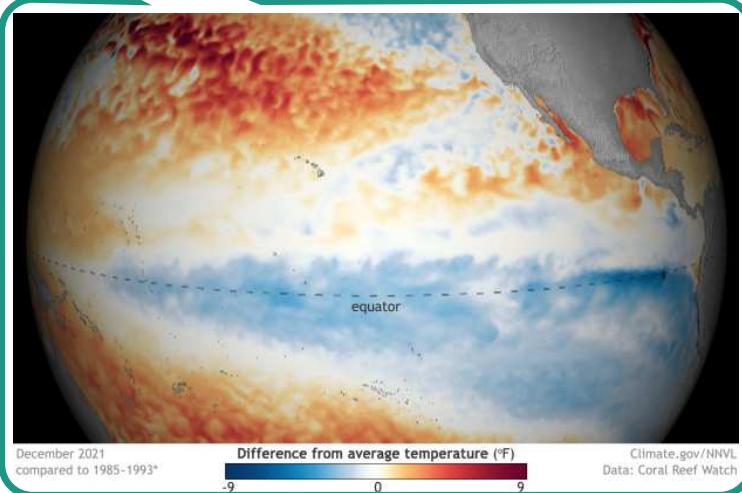
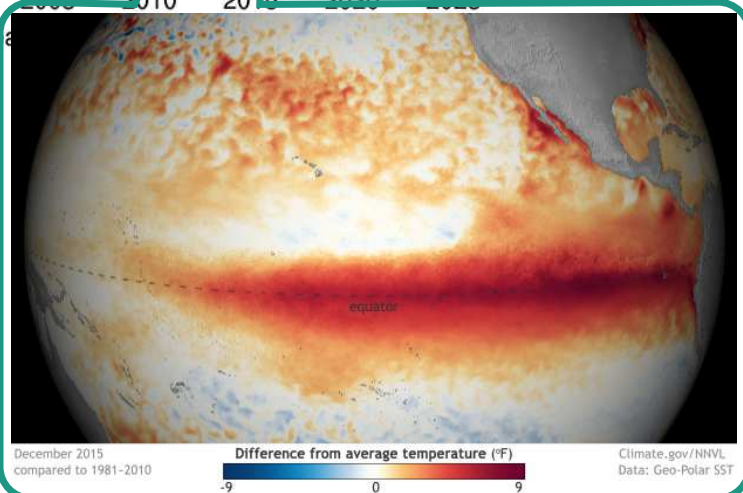
Uncertainty in climate projection

Multivariate ENSO Index Version 2 using JRA3Q



? Human-induced climate change

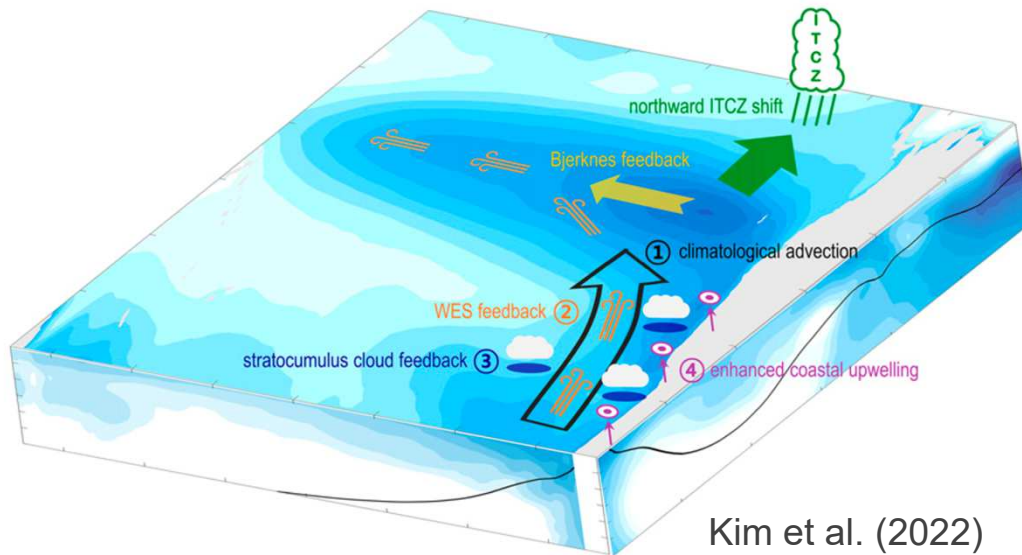
Natural (internal) climate variability



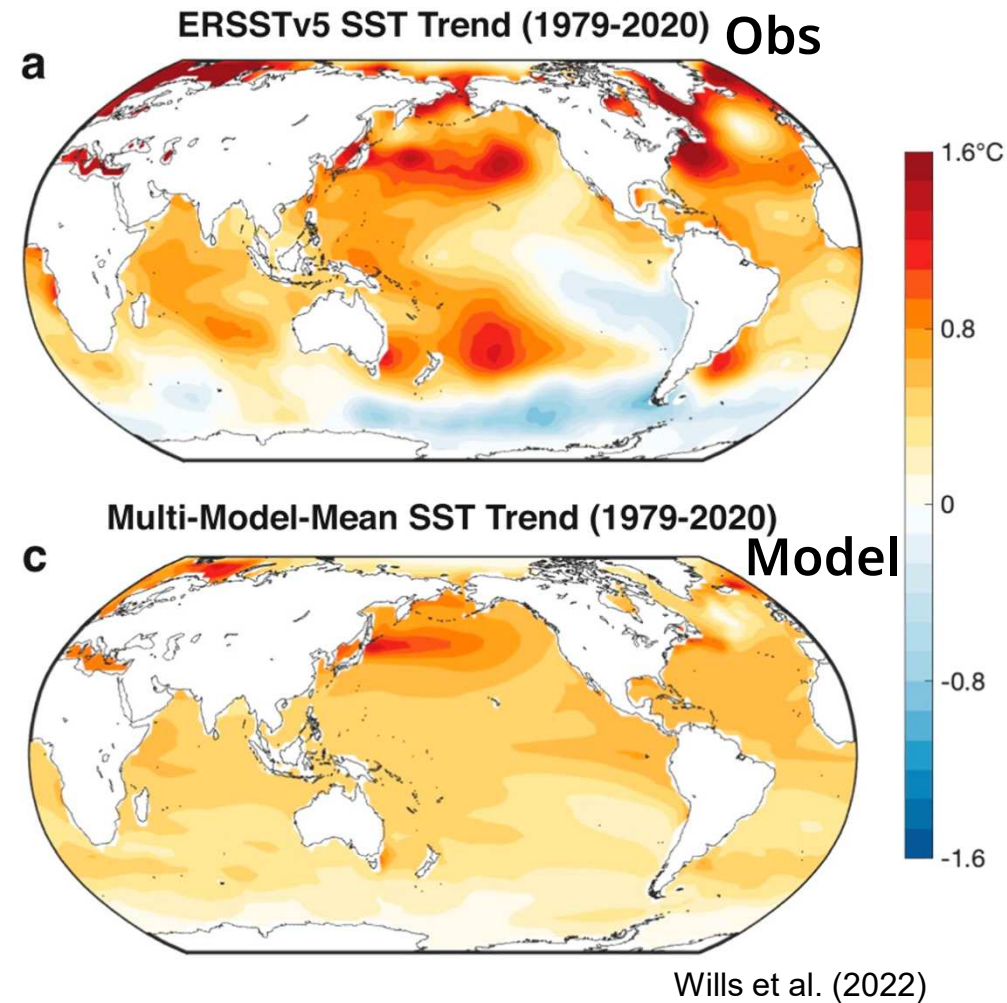
<https://www.climate.gov/maps-data/data-snapshots/data-source/sst-ens0-region-monthly-difference-average>

Cause?

- One hypothesis links the *La Niña-like* trend to the South Pacific surface temperature change



Inter-regional linkages
in the climate projection uncertainty



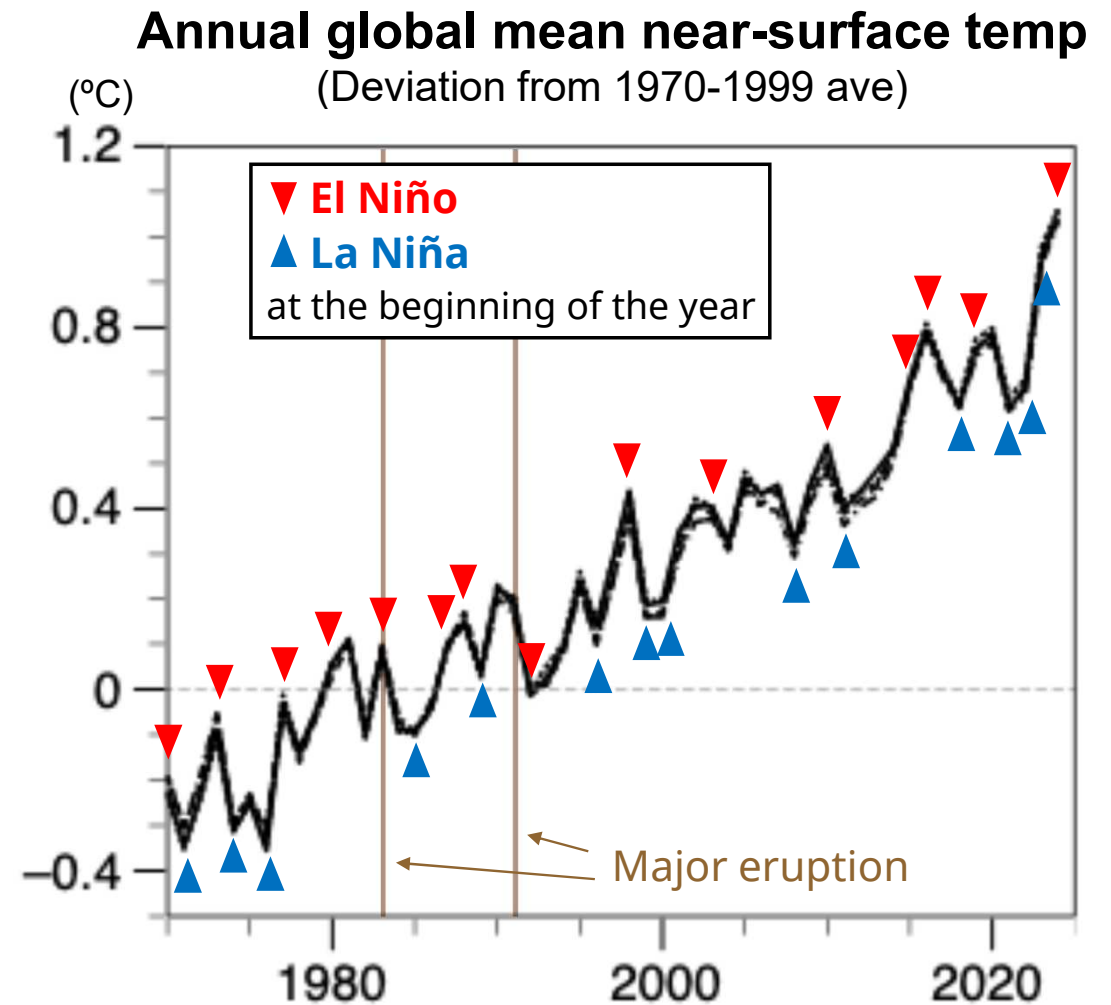
Is it important?



- 1. El Niño and La Niña affect the global mean surface temperature**
- 2. It affects regional climate change**
- 3. It affects natural climate variability and extremes**

Global mean surface temperature

- ENSO is an important driver of global mean surface temperature variability
 - El Niño → global mean temp increase
 - La Niña → decrease
- The past *La Niña-like* trend has acted to suppress global warming
- Future?

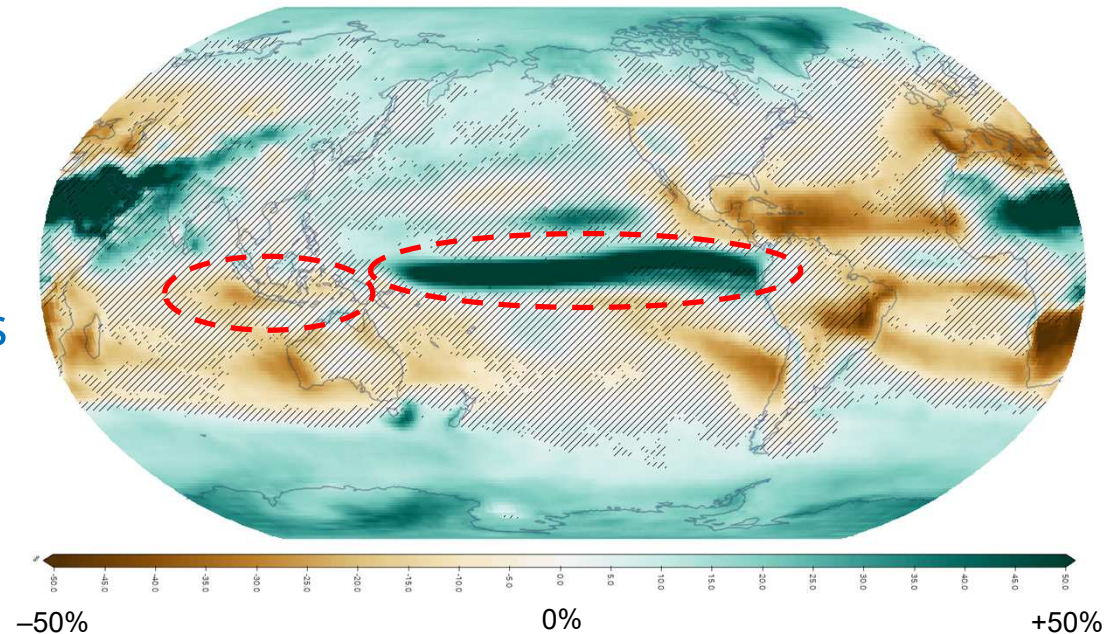


Climate change in the tropics

Precipitation change

- Increase in the eq central-eastern Pacific
- Decrease over the Maritime Continent
- These simulated changes bear some similarity to El Niño-associated anomalies ... “Warmer-gets-wetter”
+ overall wettening in the tropics

June-July-August mean precipitation change at 3°C global warming level



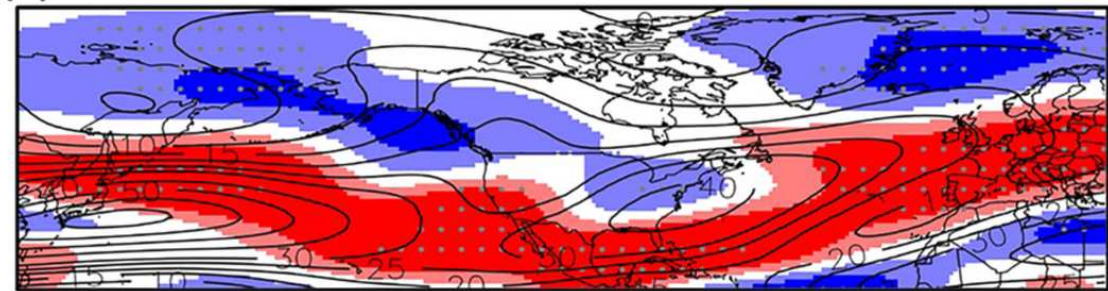
Sea level change

- The surface warming pattern affects relative sea level change b/w western and eastern parts of the basin through changing the trade winds

North Pacific jet stream and storm track

- Wintertime **Pacific jet stream** is projected to extend more downstream toward southern North America
- Similar to El Niño winters, suggesting influence of the *El Niño-like* warming
- **Extratropical storms** tend to follow the jet stream, affecting weather and extreme precipitation / droughts

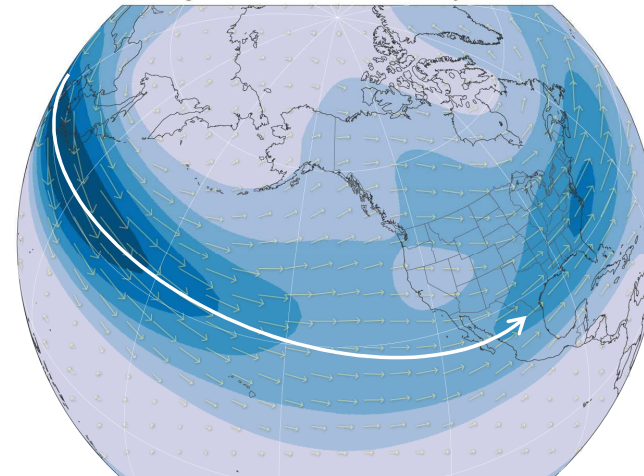
Winter, 250hPa climatological zonal wind (contours) and its change (colors)



-2 -1 0 1 2 Harvey et al. (2020)

El Niño winters

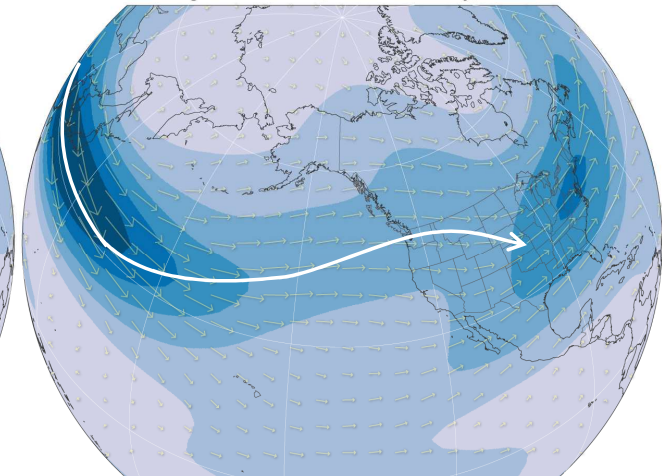
Jet stream winds during El Niño winters (December-February)



1959-2023
300-millibar wind speeds (m/s)
-10 0 10 20 30 40 50 60 40 m/s

La Niña winters

Jet stream winds during La Niña winters (December-February)



1959-2023
300-millibar wind speeds (m/s)
-10 0 10 20 30 40 50 60 40 m/s

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

NOAA Climate.gov
Data: NCEP/NCAR
Reanalysis

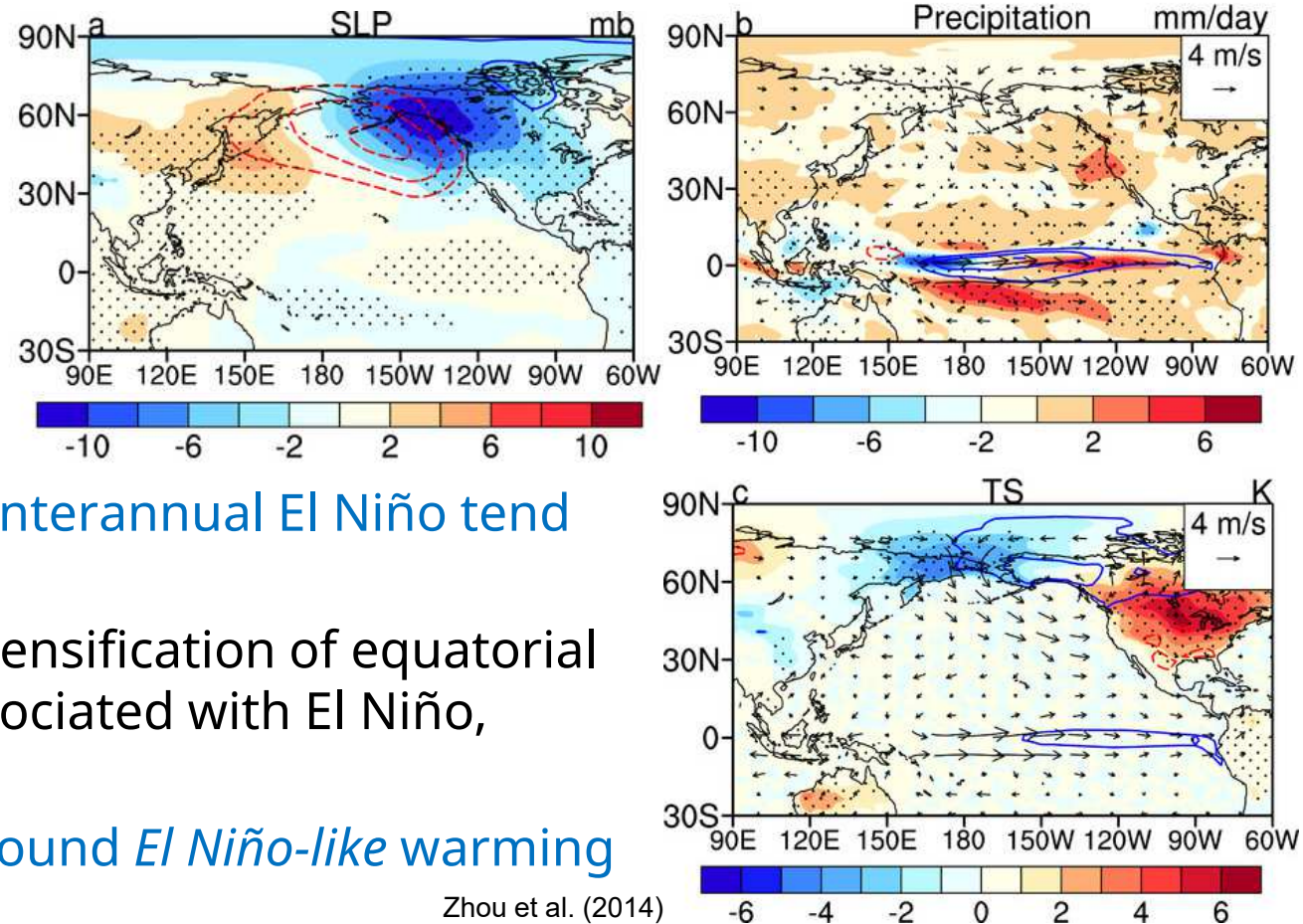
NOAA Climate.gov
Data: NCEP/NCAR
Reanalysis

ENSO teleconnection

- In addition to the mean climate change, natural (internal) year-to-year climate variability can also change
- This change can depend on the spatial pattern of background climate change

- NH climate anomalies induced by interannual El Niño tend to shift or expand eastward
- ... due to the **eastward shift** and intensification of equatorial Pacific precipitation anomalies associated with El Niño, which drive teleconnection
- This shift occurs due to the background *El Niño-like* warming

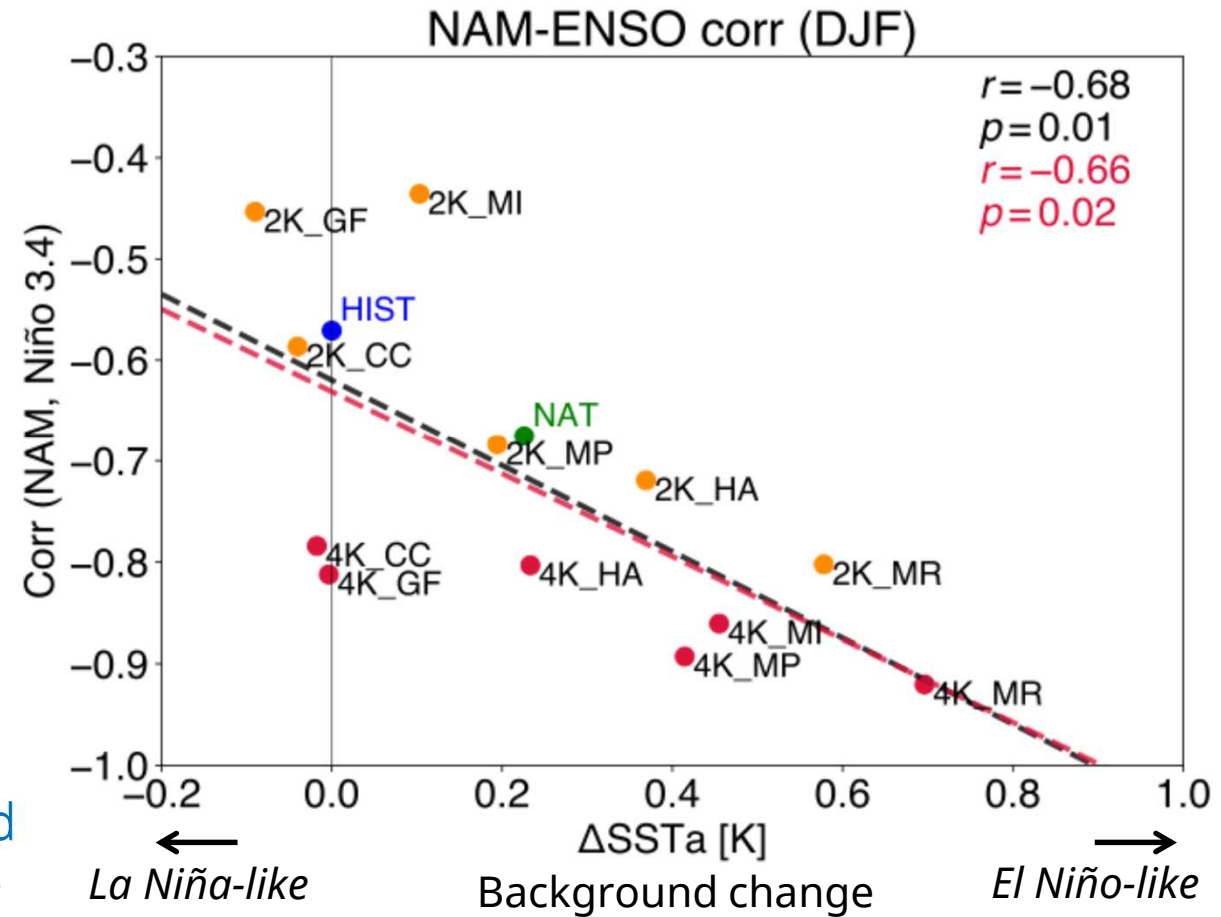
Winter anomalies associated with interannual El Niño (contours) and their changes in warmer climate (colors)



Zhou et al. (2014)

North Atlantic climate variability

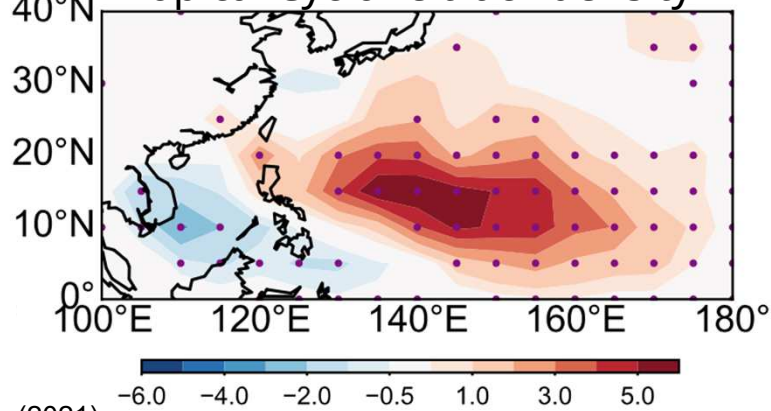
- North Atlantic Oscillation/
Northern Annular Mode
... The dominant mode of variability
over the N Atlantic
- ENSO is one of the drivers
- Global warming simulations show
an increase in their (negative)
correlation
- ... **NAO/NAM gets more predictable**
- This correlation strengthening
depends on whether the background
warming is *El Niño-like* or *La Niña-like*



Tropical cyclone activity

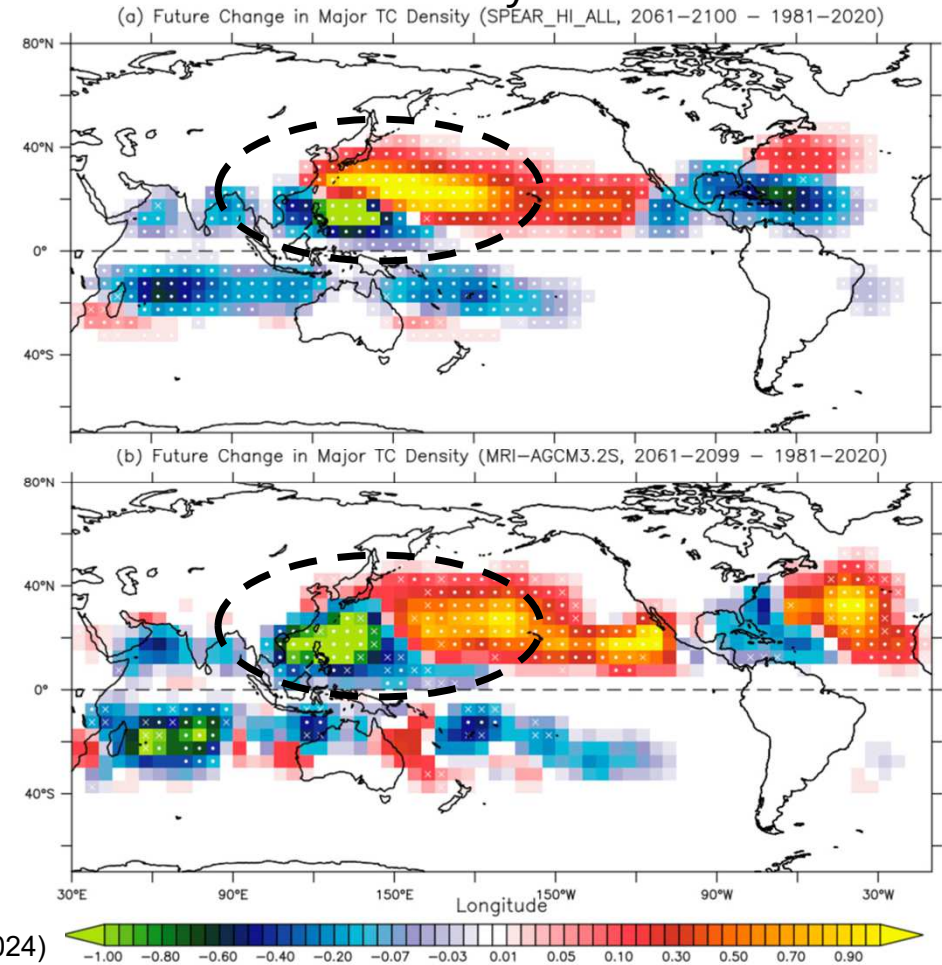
- ENSO affects tropical cyclone genesis and tracks
- Projected changes in tropical cyclone activity resembles those associated with El Niño, suggesting influence of the *El Niño-like* warming

El Niño – La Niña difference in Tropical Cyclone track density



Wu et al. (2021)

Future changes in Tropical Cyclone track density simulated by 2 models



Murakami et al. (2024)

- Inter-regional linkages in climate change projection uncertainty
 - The uncertainty is not spatially random
- **With advancements in climate models and climate change attribution, the projection can change in a globally organized manner**
- The tropical Pacific is one of the key regions for inter-regional linkages in climate projection uncertainty ... *El Niño-like or La Niña-like*
 - Global warming
 - Tropical time-mean climate
 - North Pacific jet stream and storm track
 - ENSO teleconnection and ENSO linkage with NAO/NAM
 - Pacific tropical cyclone activity
- Resolving this issue needs time: **Adaptation planning recognizing this uncertainty**