Climate variability and change in the Pacific

Past Trends and future projections

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Pacific Climate has changed

Increased frequency of large-scale heatwaves and record-high temperatures

Increased Ocean temperatures and ocean acidification

Increased rainfall in west Equatorial Pacific and Reduced rainfall south of the equator (SPCZ)

An increase in heavy rainfall

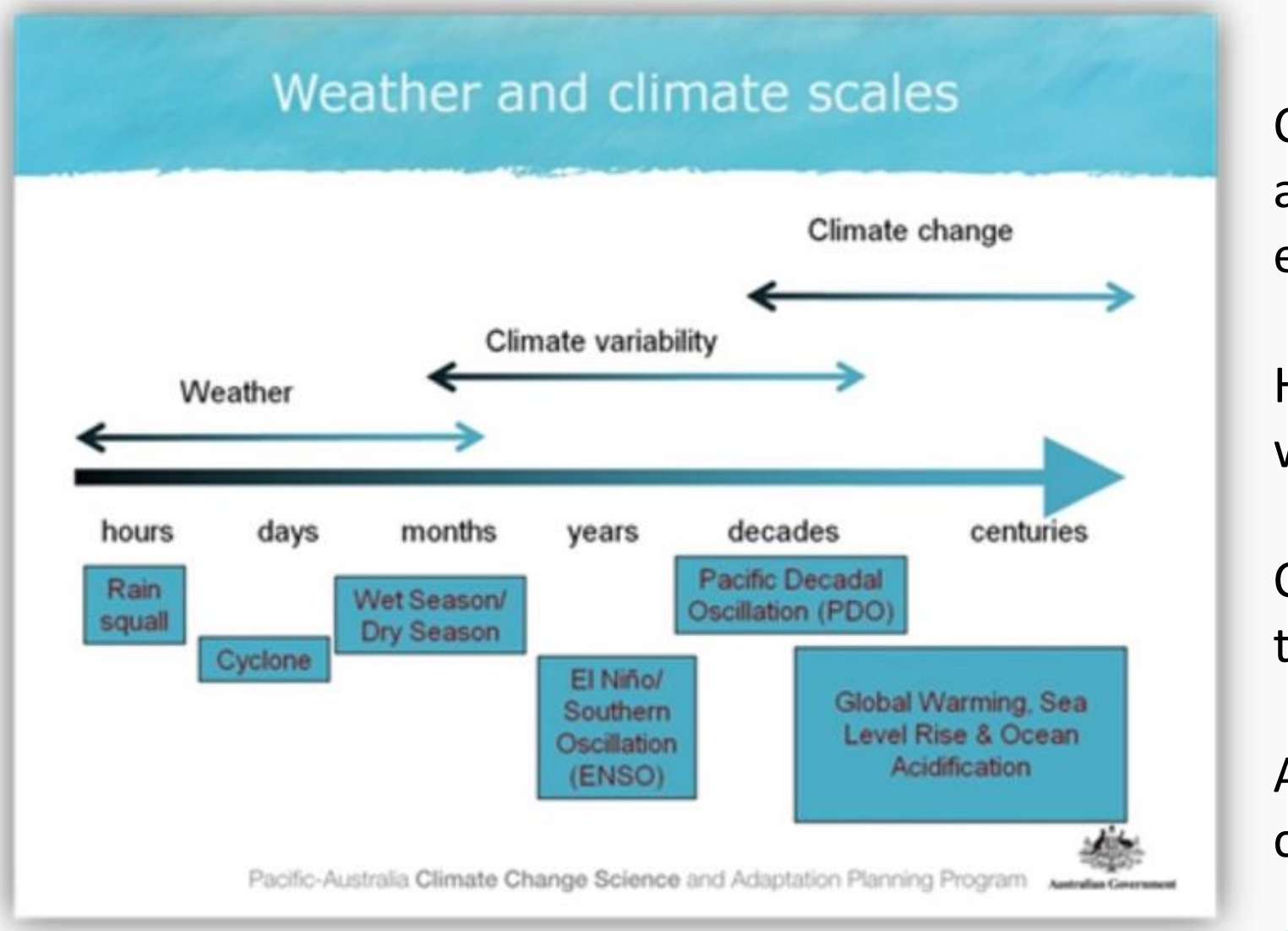
Tropical Cyclones show no significant trend

Increased frequency of coastal storm surge inundation with rising Sea Levels

- Pacific is a region of large variability (i.e. ENSO) impacting the ability to separate climate change from natural climate variability
- Climate change may impact climate variability and extreme climate events

IPCC AR6

Timescales for weather, climate variability and climate change



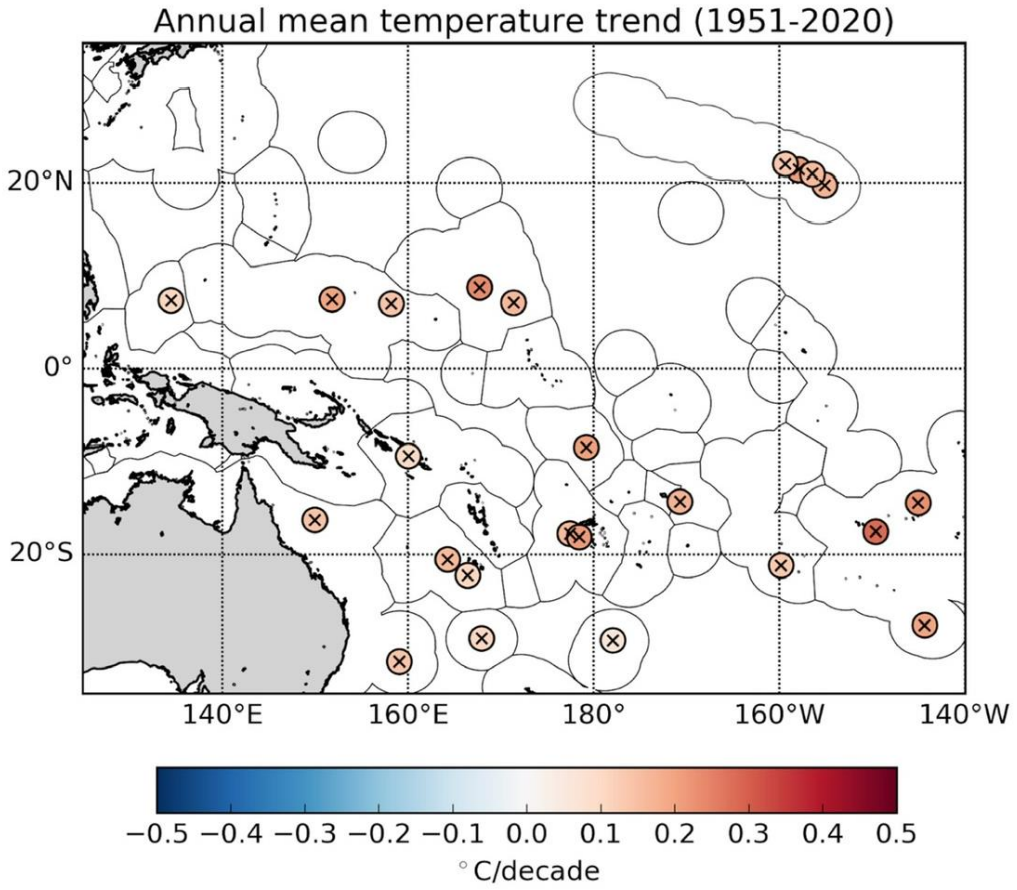
Climate change impacts are associated with extreme climate events (e.g. flooding)

How does climate influence the weather?

Chronic – rising mean temperatures (mean change)

Acute – heatwaves (extreme climate event)

Temperature Trend (1951-2020)



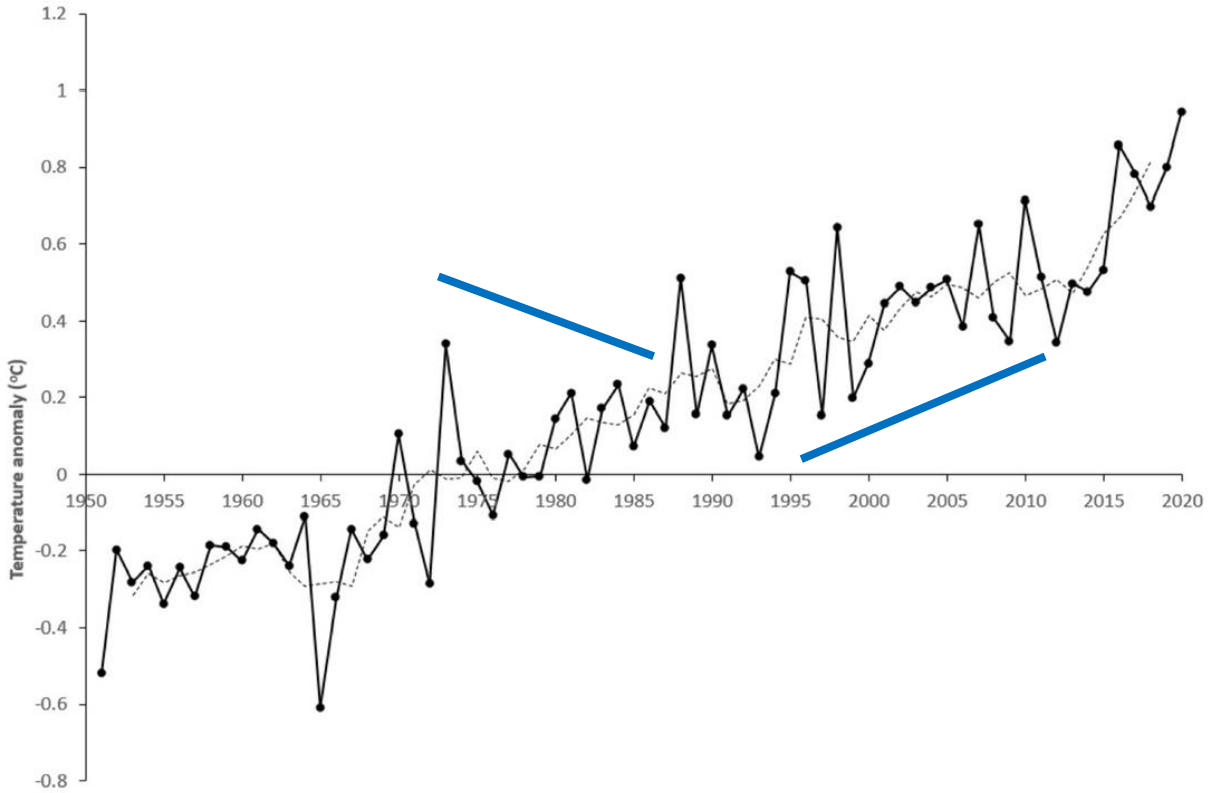


Figure 7: Regional annual mean temperature anomalies relative to 1961-1990 climatology. The dashed line represents a five-year running average.

CMIP6

SSPs – Shared Socioeconomic Pathways

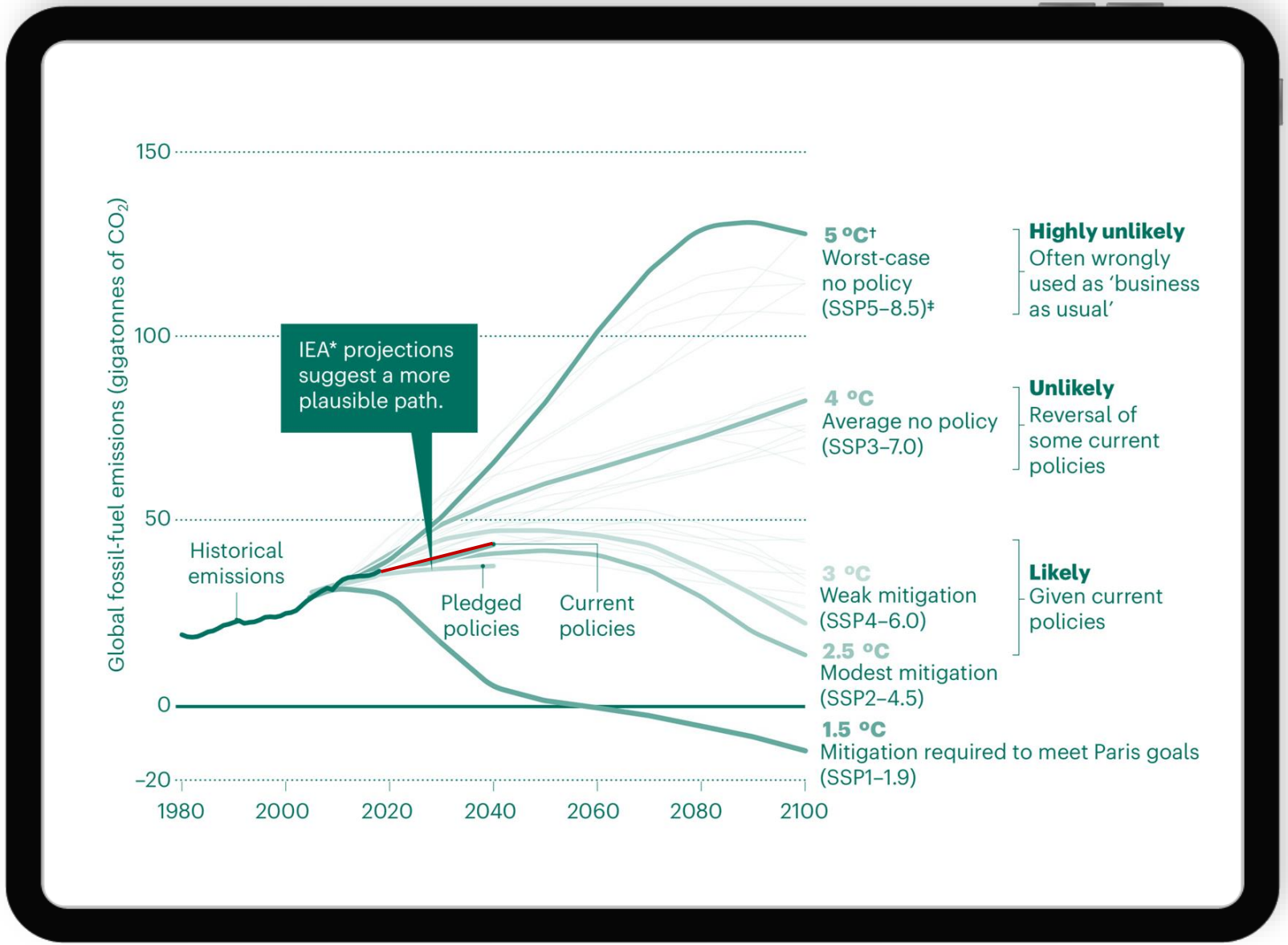
Range in possible scenarios

SSP3-7.0

SSP1-2.6

Comms challenge

People expect we are on the highest scenario and the low option is impossible

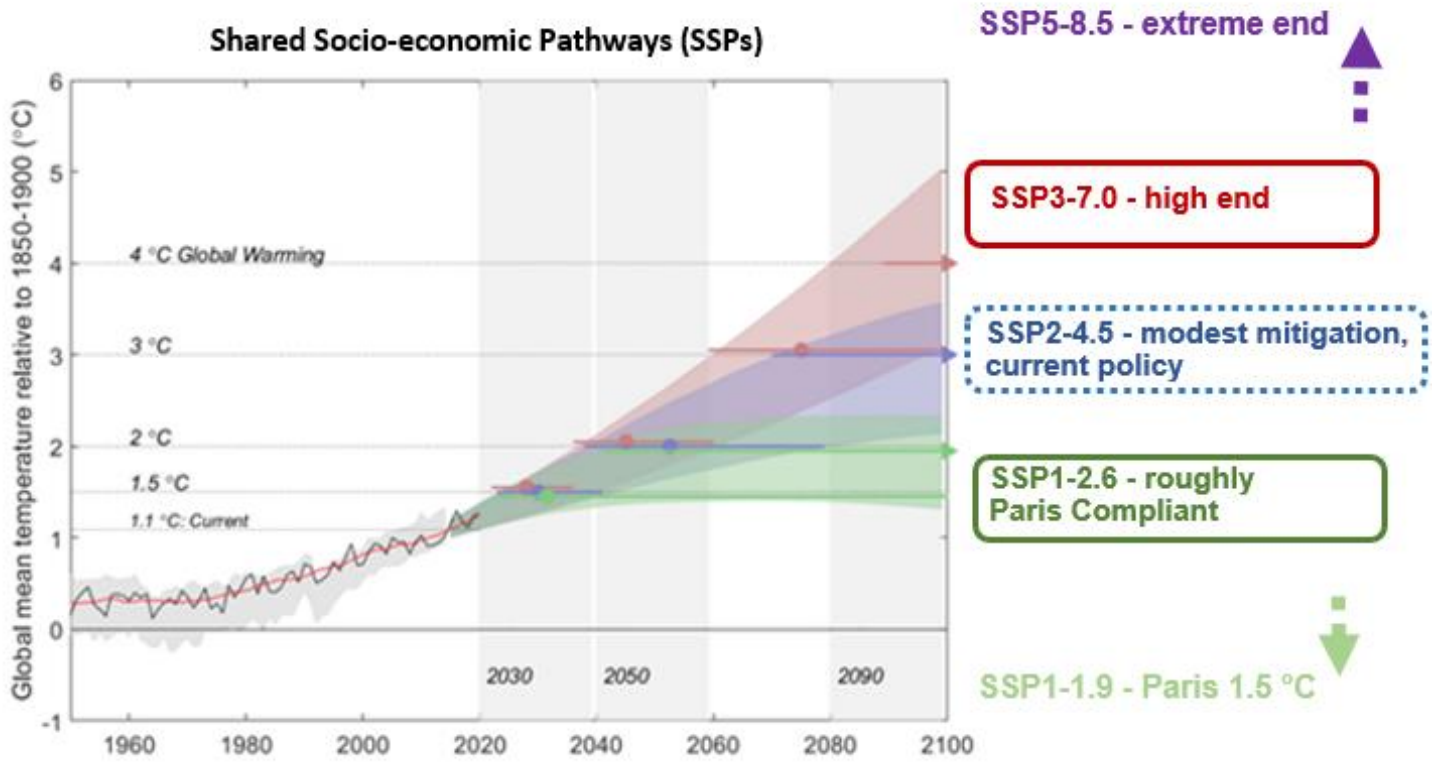


Hausfather and Peters 2020

Our future climate: Australian Climate Risk Assessment approach

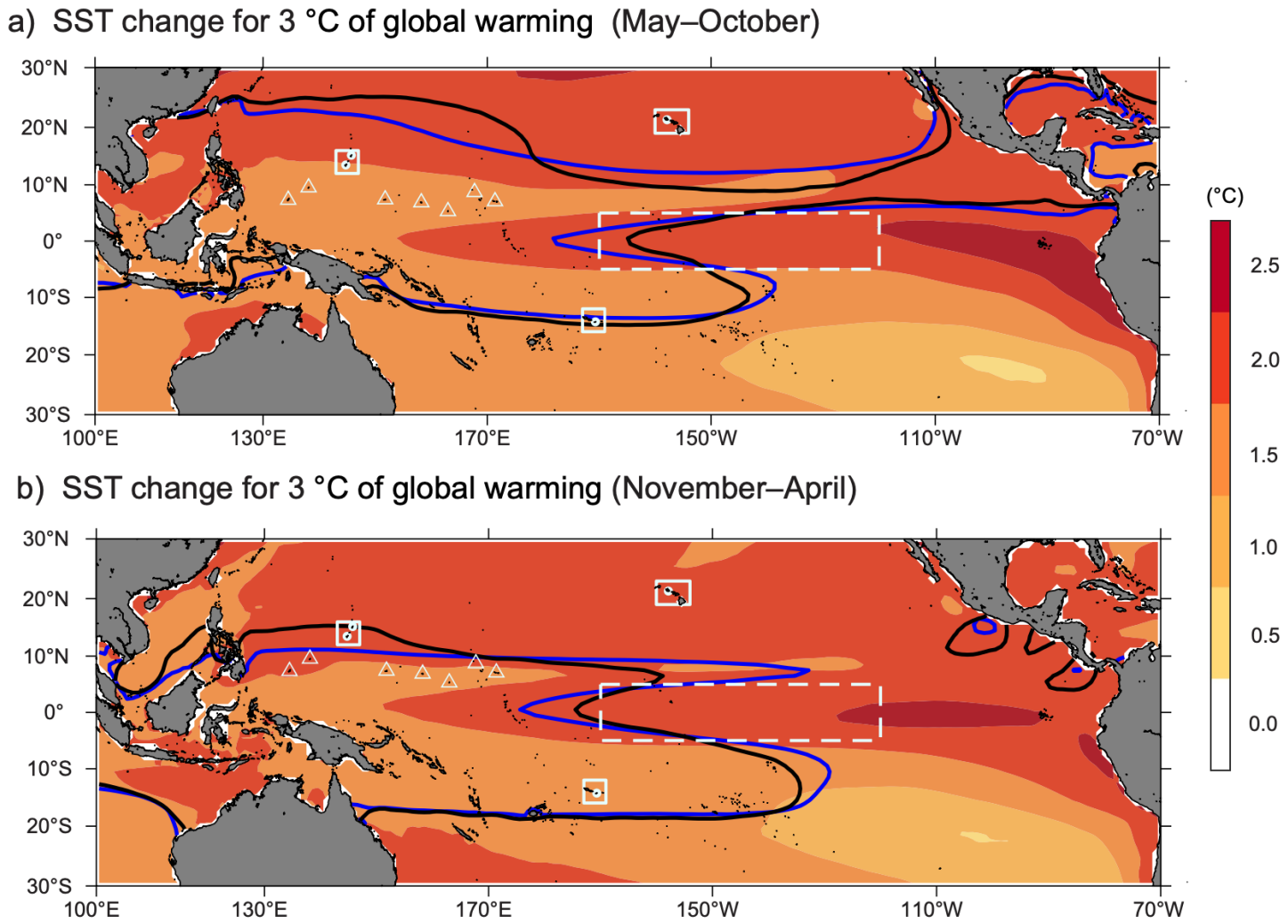
Moving away for Shared Socio-economic Pathways (SSPs) and Representative Concentrations Pathways (RCP's) to Global Warming Levels to characterise our future climate

Time horizon	Global Warming Level (GWL)
2050	GWL 1.5 (low emissions) GWL 2 (high emissions)
2090	GWL 2 (low emissions) GWL 3 (high emissions)



Gross et al., 2023 and IPCC AR6

Future Sea Surface Temperature



Surface Ocean warms less than global mean temperature

Warming ocean increases the frequency, duration and magnitude of marine heatwaves

Black contour – obs 28°C
Blue contour – simulated historical 28°C

Dhage and Widlansky 2022

Marine Heatwaves: extreme ocean events and their impacts

Fish/invertebrate kills in Fiji and Vanuatu (Feb 2016)

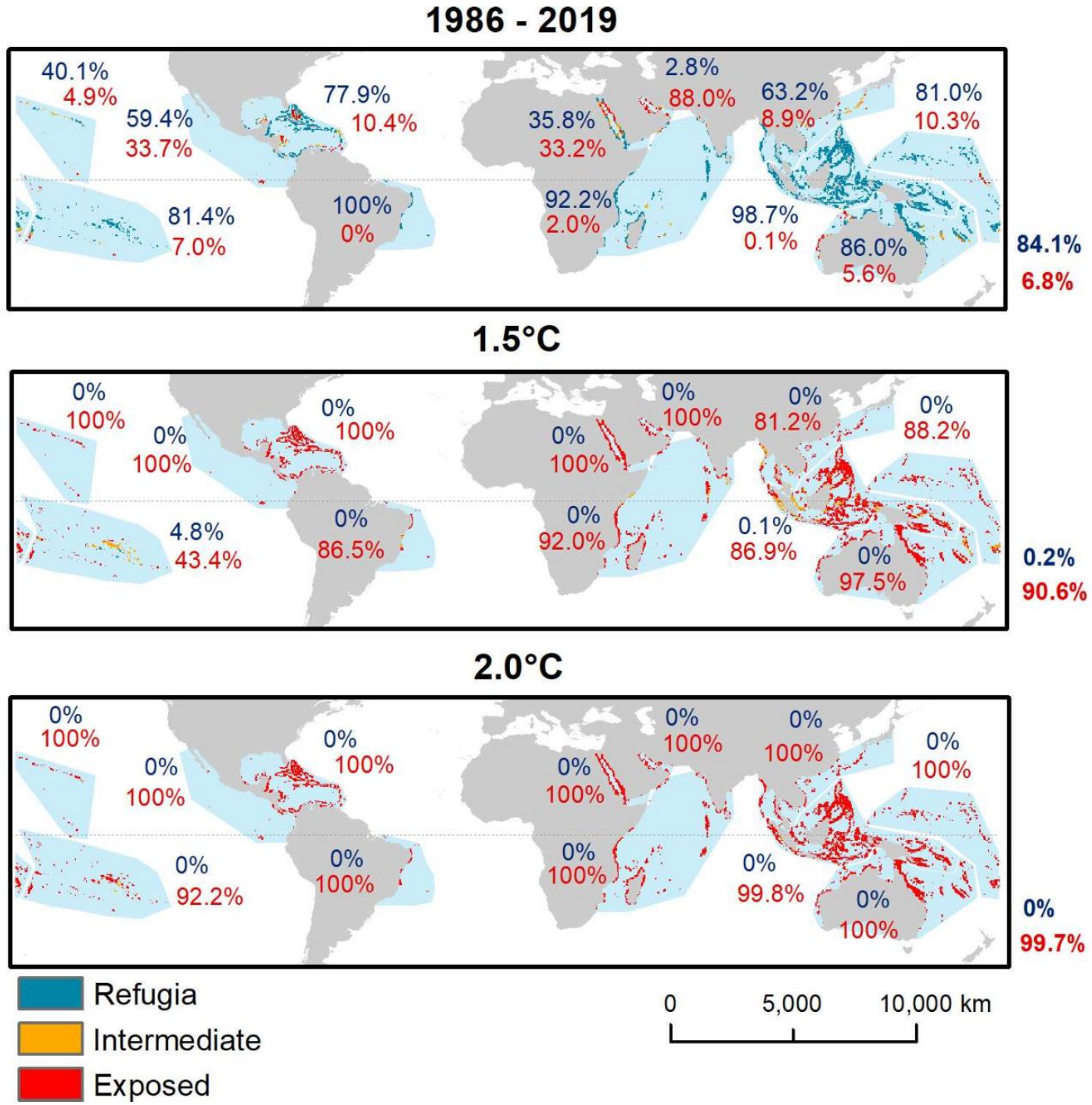
Source: Tai Minio Wotaniman via Vanuatu Daily Post

Pacific coral bleaching: Samoa

Source: Satoa et al. 2016

Seagrass loss in Shark Bay, WA (2011)

Source: www.conversation.com

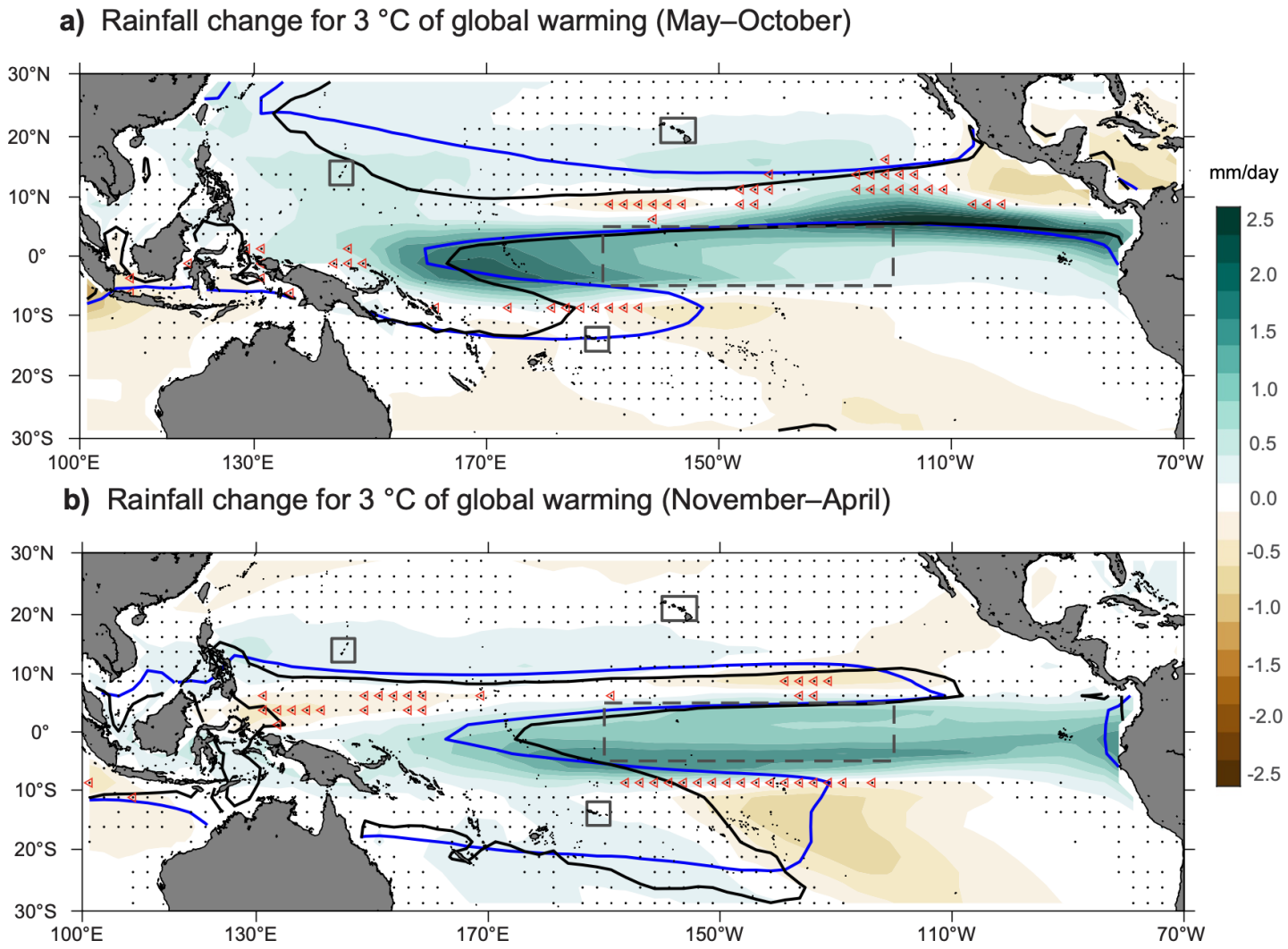


Suitable coral reef habitat based on temperature

Coral Bleaching duration, magnitude and frequency increases with warming impacting suitable habitat

Dixon et al., 2022

Future mean rainfall



Projected increase in mean rain fall along equator with some drying trends off equator

Black contour – obs. 5 mm/day

Blue contour – simulated historical 5mm/day

Dhage and Widlansky 2022

Future Pacific Climate

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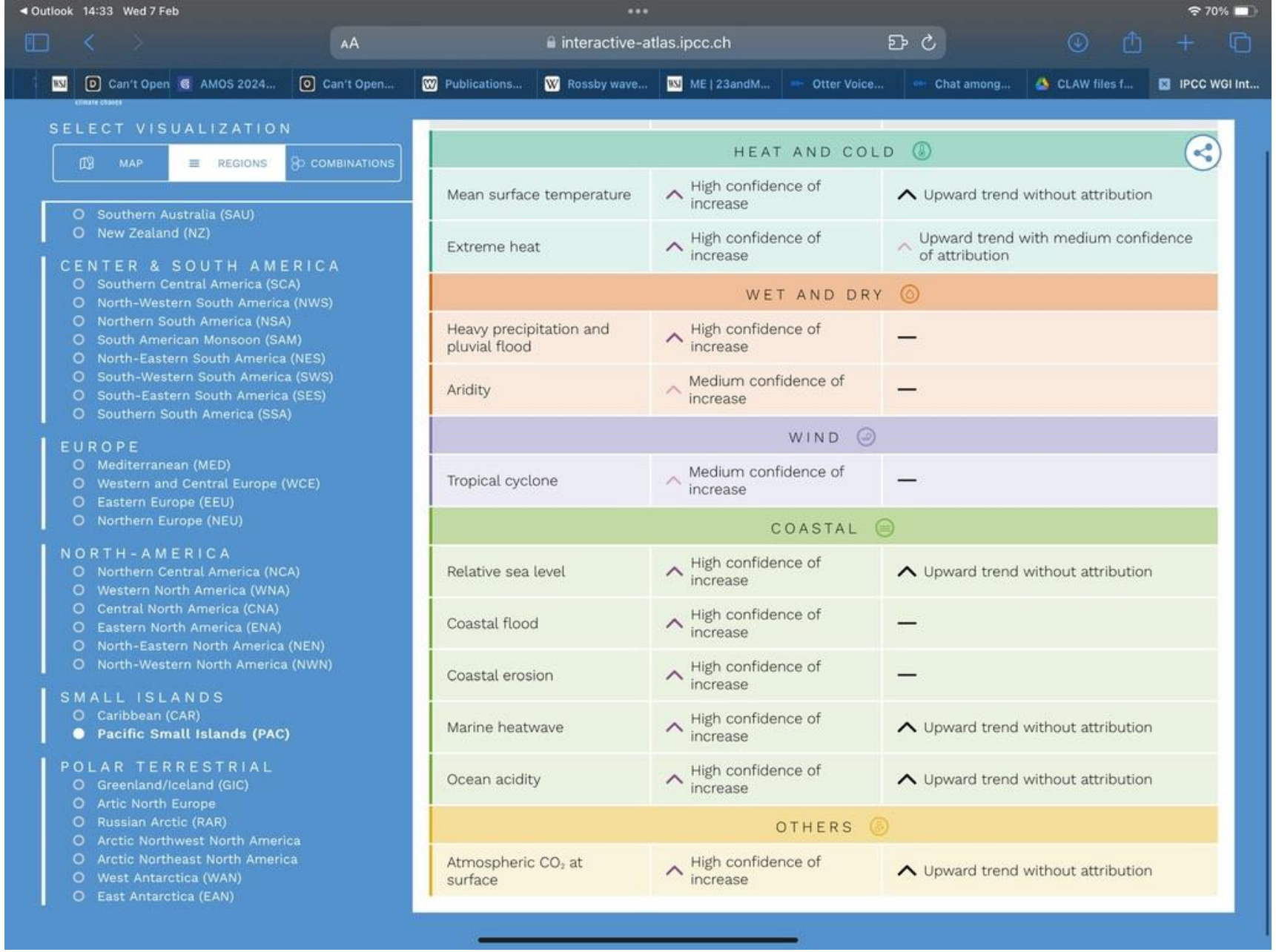
Tropical Cyclones show no significant trend

- Pacific is a region of large variability (i.e. ENSO) which will be impacted by future climate change
- Climate change will impact extreme climate events

IPCC AR6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Chat among...
CLAW files f...
IPCC WGI Int...
SELECT VISUALIZATION
MAP
REGIONS
COMBINATIONS
Southern Australia (SAU)
New Zealand (NZ)
CENTER & SOUTH AMERICA
Southern Central America (SCA)
North-Western South America (NWS)
Northern South America (NSA)
South American Monsoon (SAM)
North-Eastern South America (NES)
South-Western South America (SWS)
South-Eastern South America (SES)
Southern South America (SSA)
EUROPE
Mediterranean (MED)
Western and Central Europe (WCE)
Eastern Europe (EEU)
Northern Europe (NEU)
NORTH-AMERICA
Northern Central America (NCA)
Western North America (WNA)
Central North America (CNA)
Eastern North America (ENA)
North-Eastern North America (NEN)
North-Western North America (NWN)
SMALL ISLANDS
Caribbean (CAR)
Pacific Small Islands (PAC)
POLAR TERRESTRIAL
Greenland/Iceland (GIC)
Artic North Europe
Russian Arctic (RAR)
Arctic Northwest North America
Arctic Northeast North America
West Antarctica (WAN)
East Antarctica (EAN)
HEAT AND COLD
Mean surface temperature
High confidence of increase
Upward trend without attribution
Extreme heat
High confidence of increase
Upward trend with medium confidence of attribution
WET AND DRY
Heavy precipitation and pluvial flood
High confidence of increase
—
Aridity
Medium confidence of increase
—
WIND
Tropical cyclone
Medium confidence of increase
—
COASTAL
Relative sea level
High confidence of increase
Upward trend without attribution
Coastal flood
High confidence of increase
—
Coastal erosion
High confidence of increase
—
Marine heatwave
High confidence of increase
Upward trend without attribution
Ocean acidity
High confidence of increase
Upward trend without attribution
OTHERS
Atmospheric CO_2 at surface
High confidence of increase
Upward trend without attribution

Contact us

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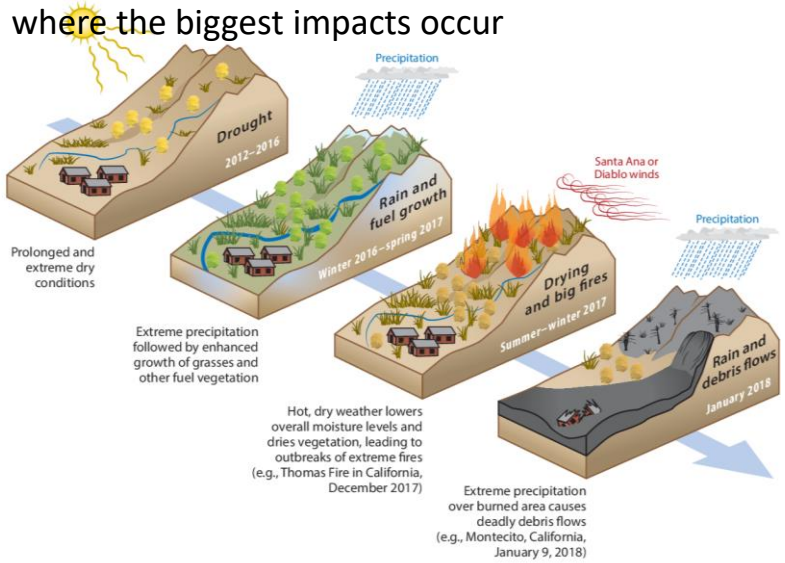
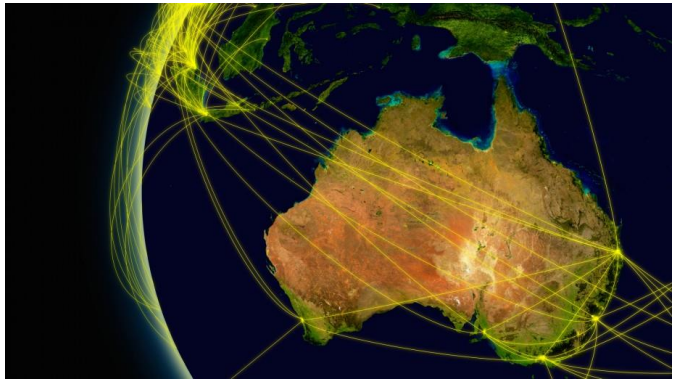
Some additional points : complex risk, global impacts and tipping points

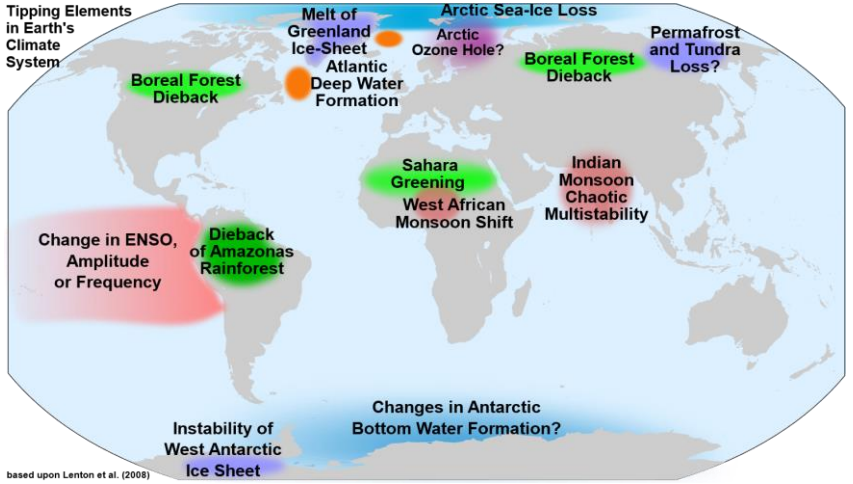
Increased Variability: Compound and consecutive extremes, cascading impacts can be where the biggest impacts occur





Connected: climate change cross borders and impacts Trade, Migration, Food Security, Conflict, ...

Known Unknowns: Reaching global climate 'Tipping Points' may mean abrupt change, effects on Australia beyond projections shown here



Also consider regional 'regime shifts' with local abrupt change 'tipping points' within systems

Sequence of extremes California 2018 (AghaKouchak et al. 2020 Climate Extremes and Compound Hazards in a Warming World. *Annual Review of Earth and Planetary Sciences*)

Rainfall Trends

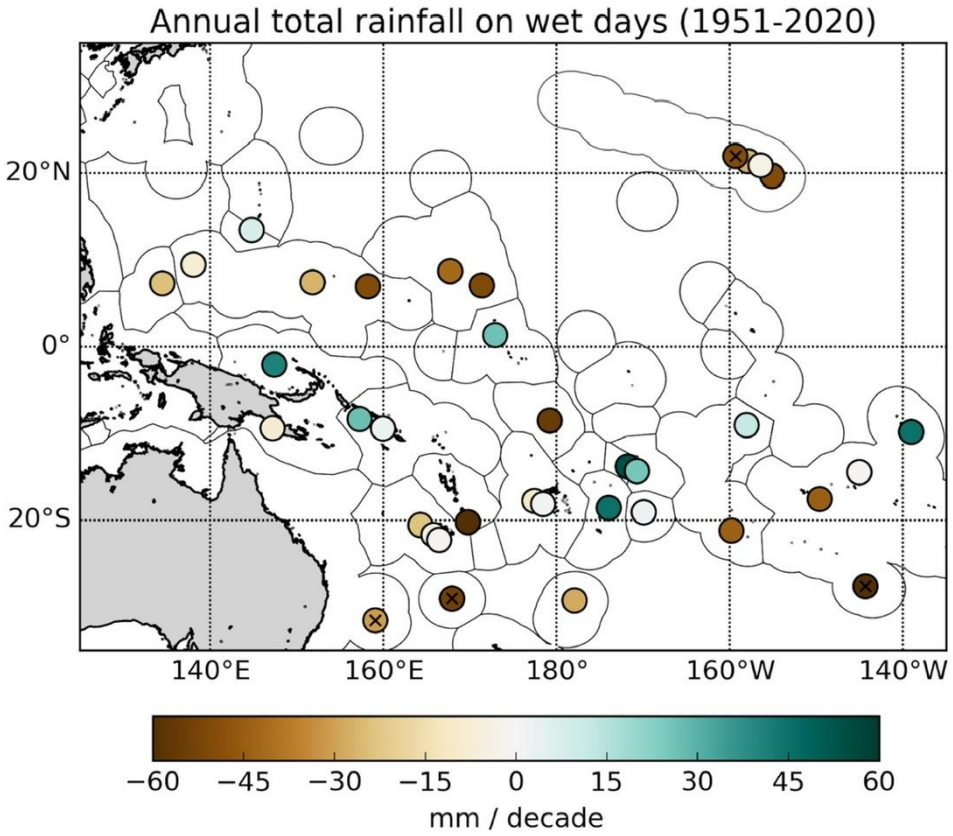


Figure 12: Trends in annual total rainfall on wet days over 1951-2020. Circles with 'x' represent trends statistically significant at the 95% level.

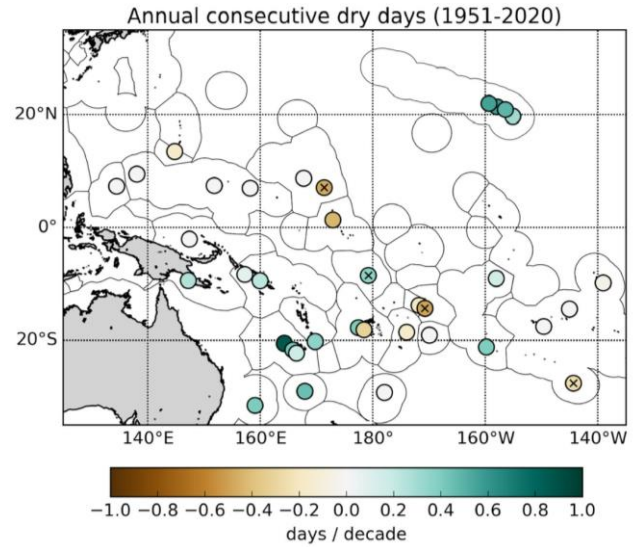


Figure 13: Trend in annual consecutive dry days over 1951-2020. Circles with 'x' represent trends statistically significant at the 95% level.

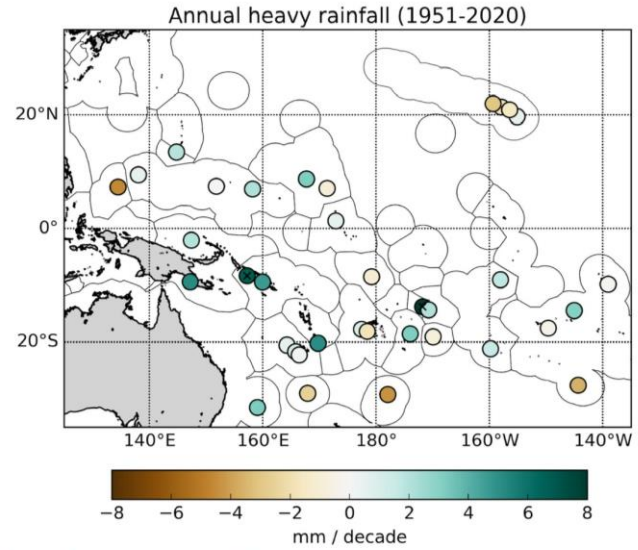
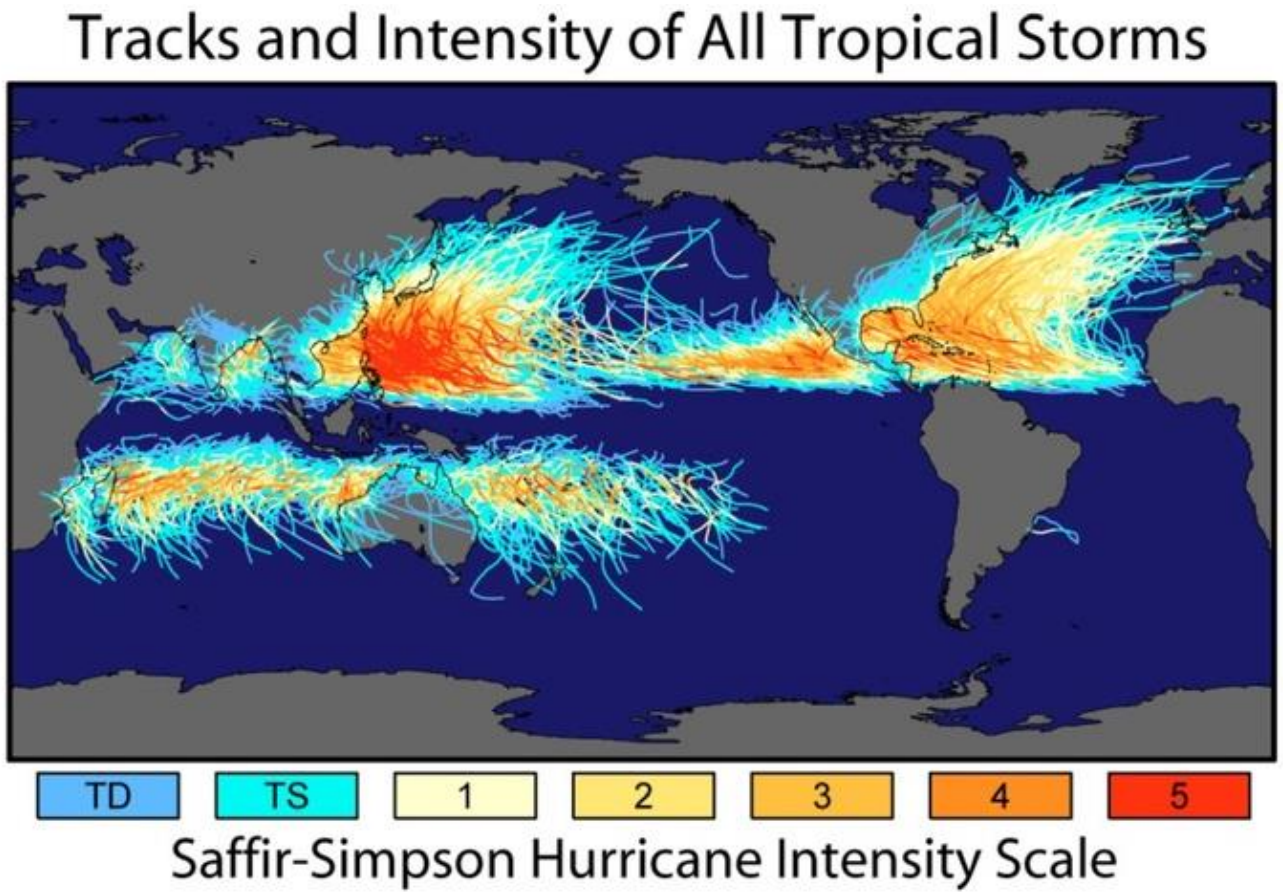


Figure 14: Trend in annual heavy rainfall over 1951-2020. Circles with 'x' represent trends statistically significant at the 95% level.

Tropical Cyclones



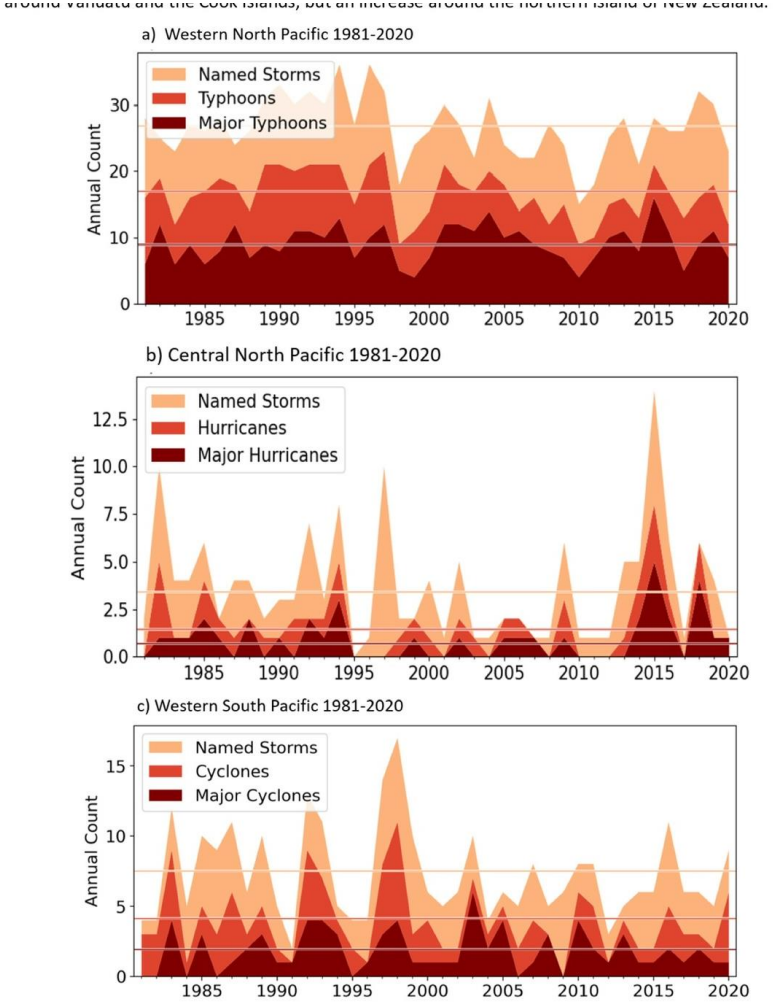


Figure 15. Tropical cyclone (TC) activity 1981-2020. Storm counts for: a) Western North Pacific, b) Central North Pacific, c) Western South Pacific. Major cyclones with winds greater than or equal to 110 kt and Major hurricanes with winds greater than or equal to 96 kt (110 mph).

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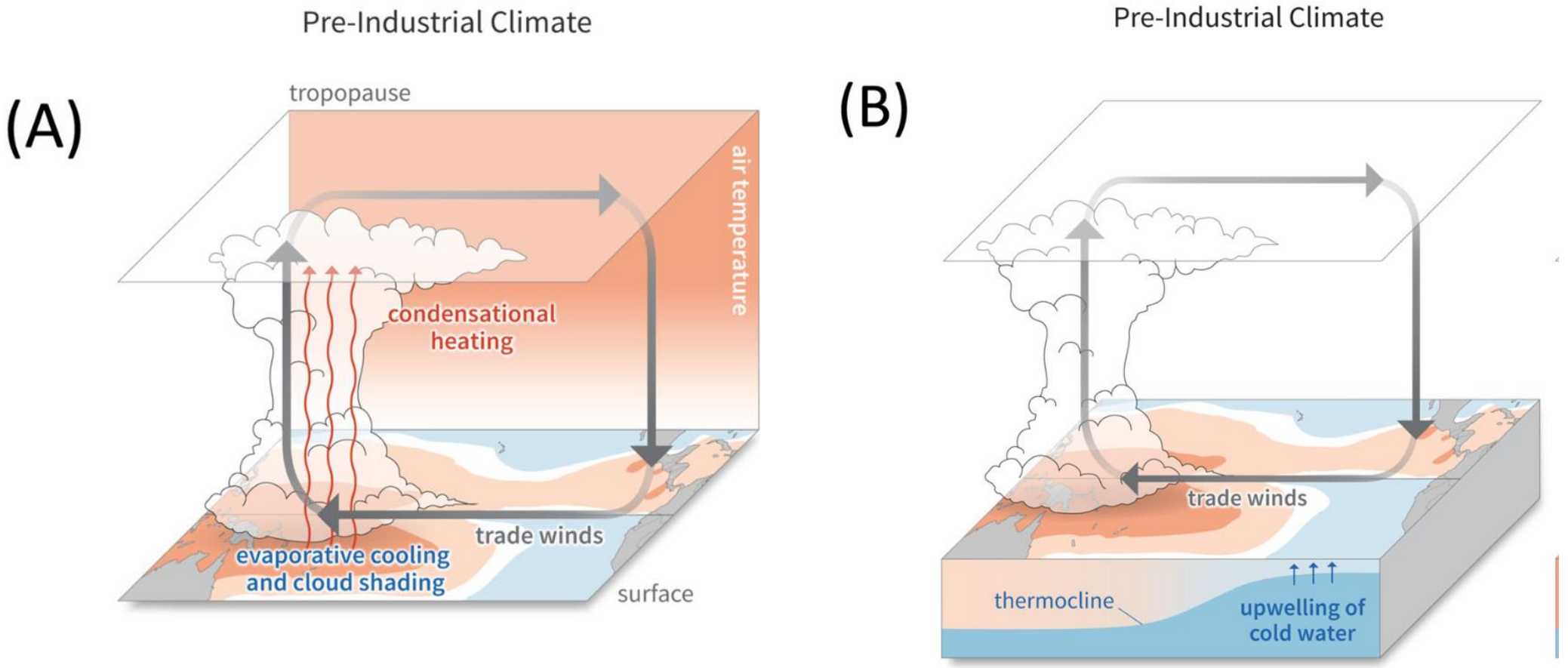
Australian Bureau of Meteorology, Pacific Island Climate Change Monitor: 2021

Climate Variability

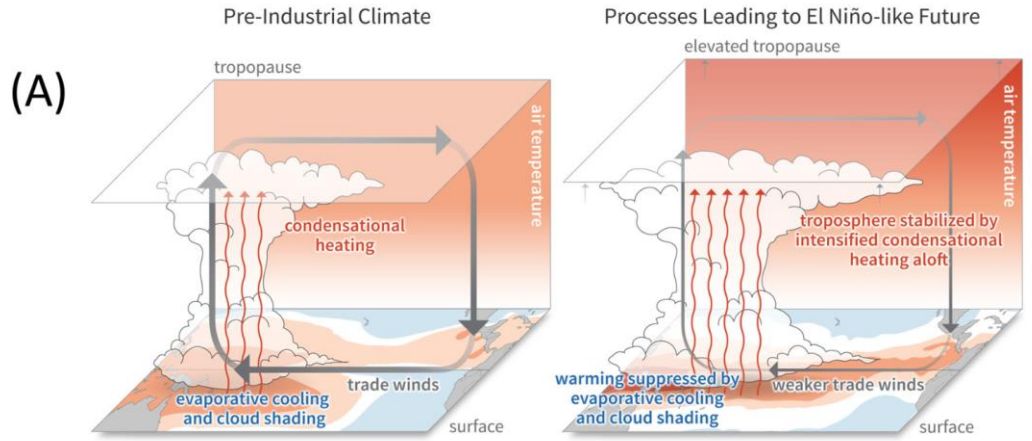


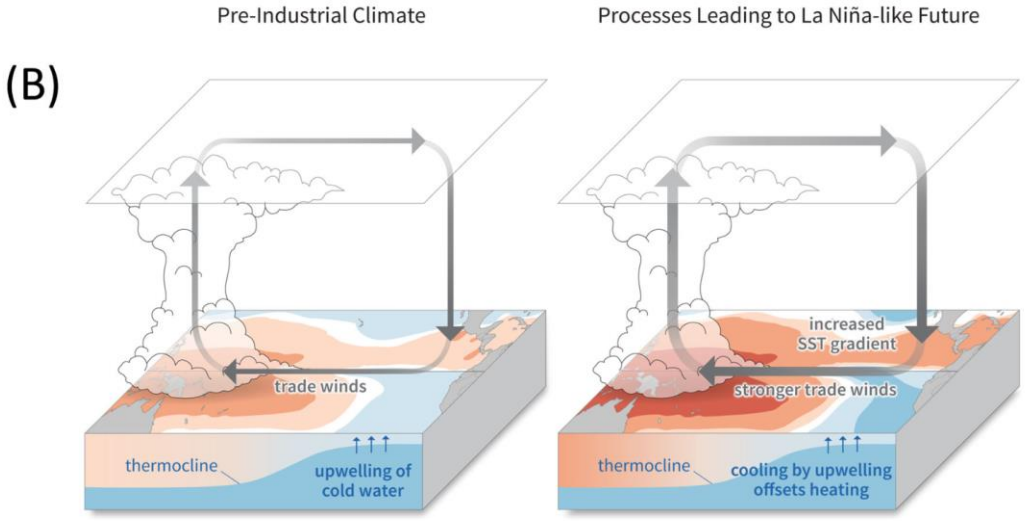
El Niño

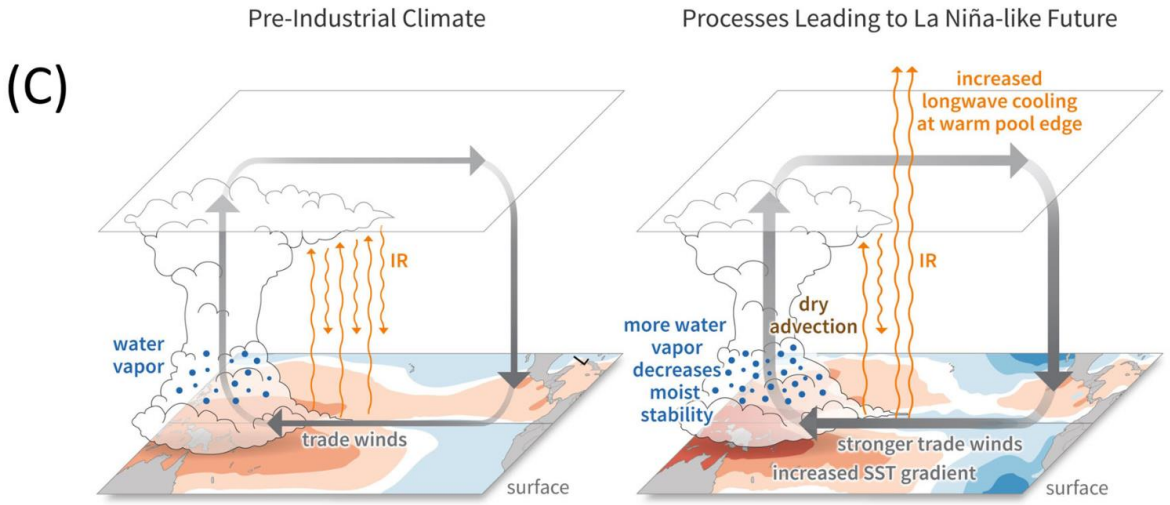
La Niña

Lee et al. 2022

ENSO response to climate change – multiple ideas

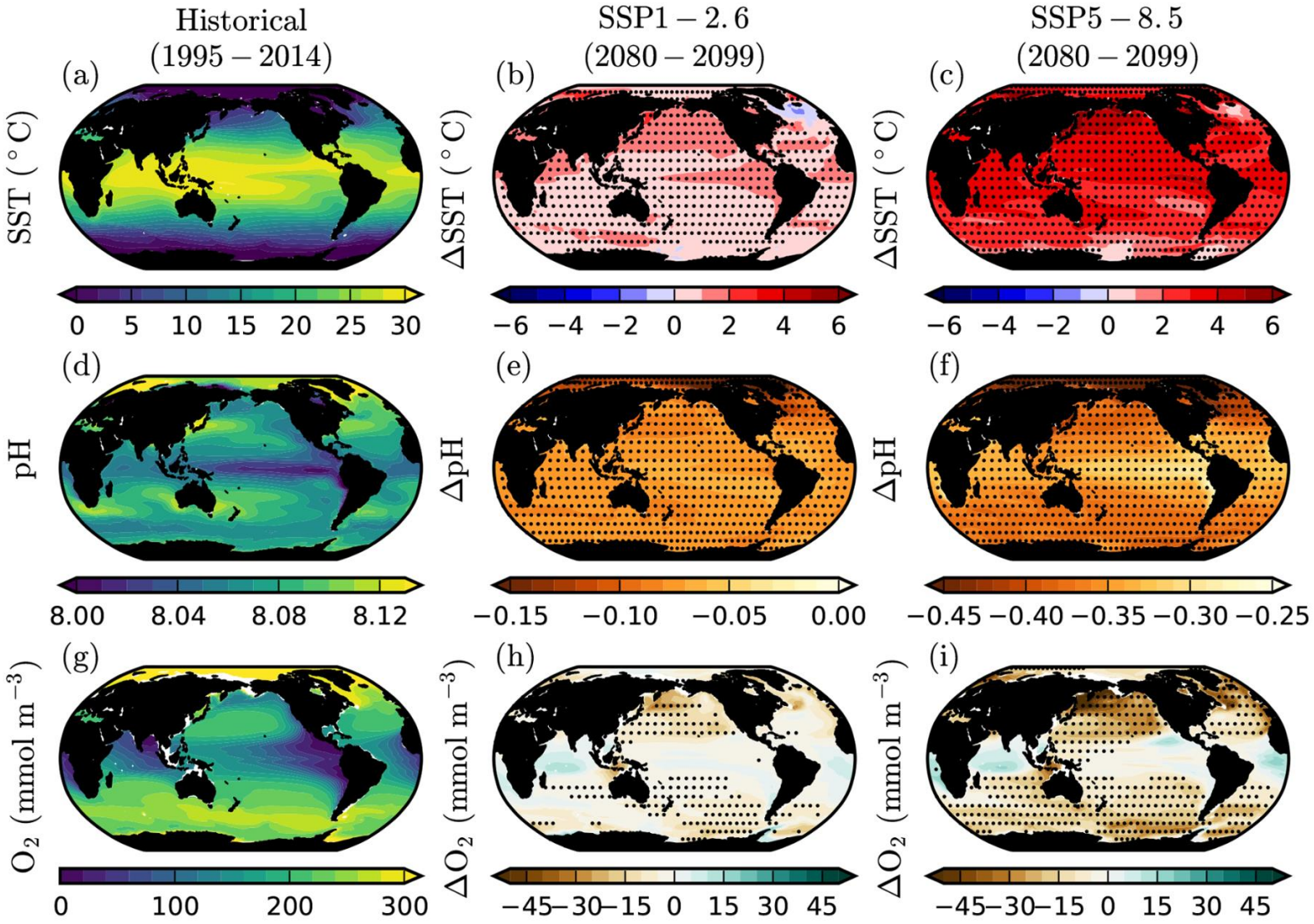






Lee et al. 2022

BGC fields from CMIP6 multi-model mean



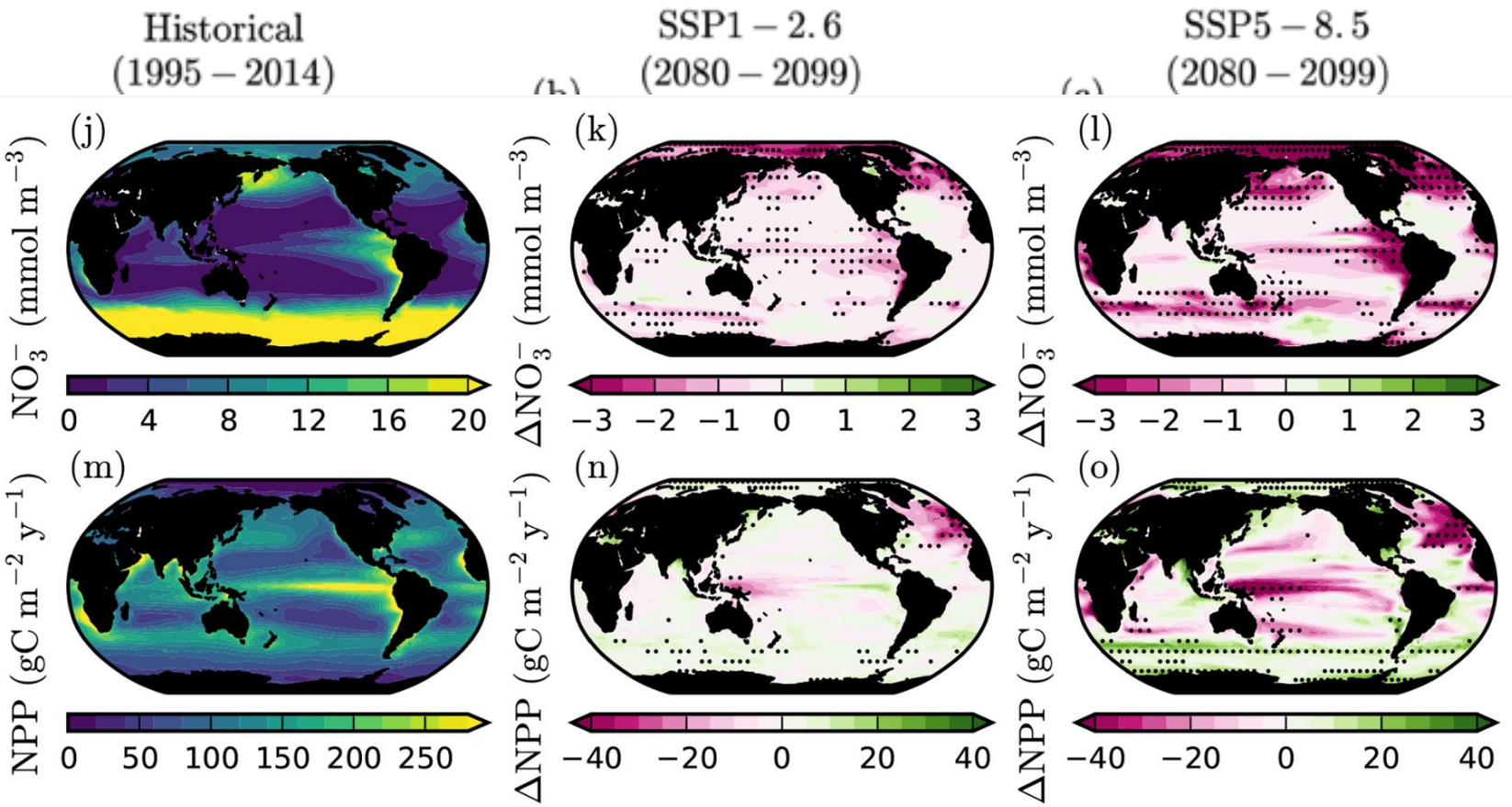
SST

Surface pH

Interior oxygen (100-600m)

Kwiatkowski et al. 2020

BGC fields from CMIP6 multi-model mean



Surface Nitrate

Upper Ocean
Net Primary Production

More El Nino like state leads to reduced upwelling of nutrients in the eastern Equatorial Pacific and reduced NPP

Kwiatkowski et al. 2020