

Climate change in the Pacific region: The physical setting

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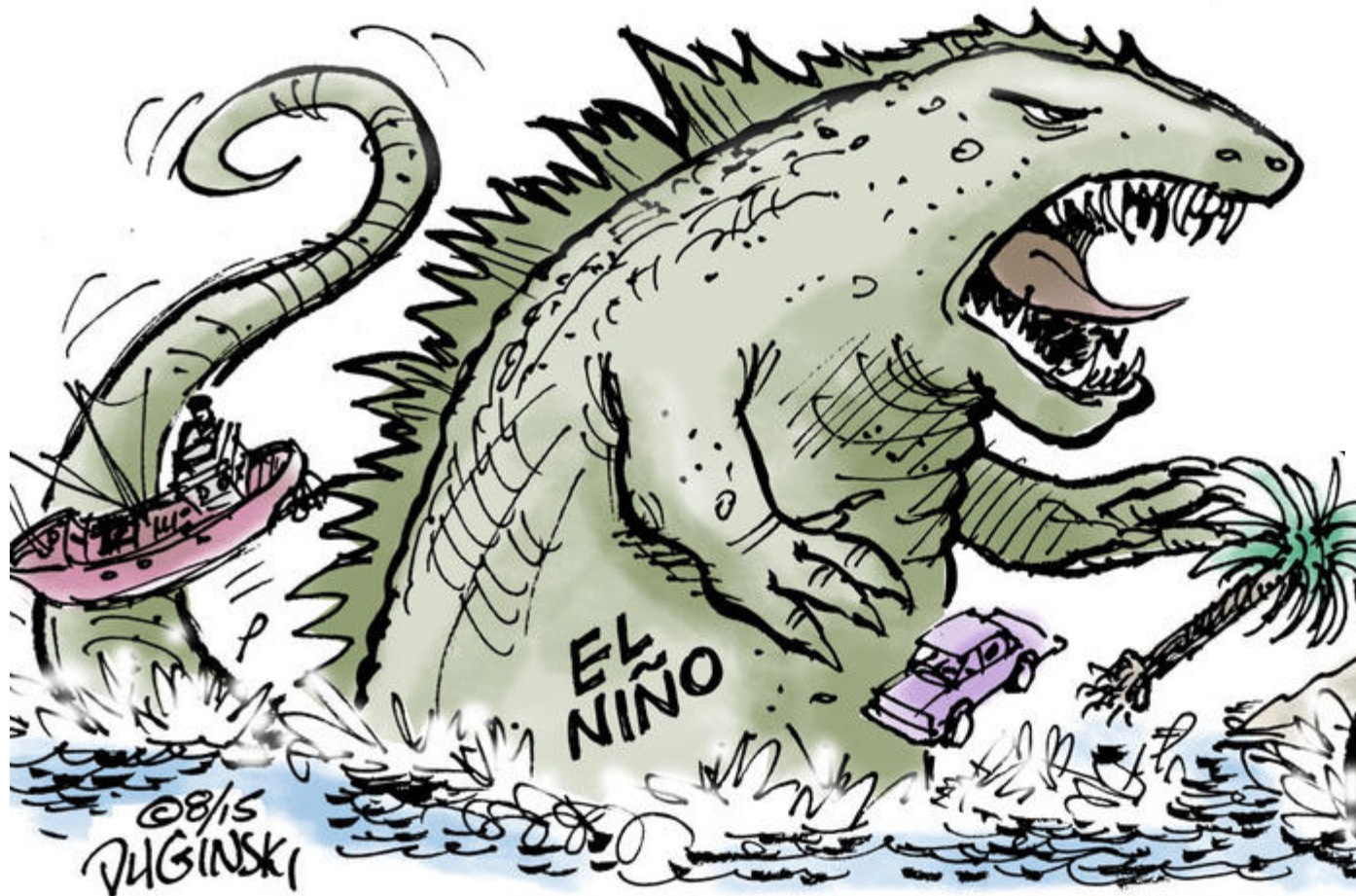


U.S. DEPARTMENT OF
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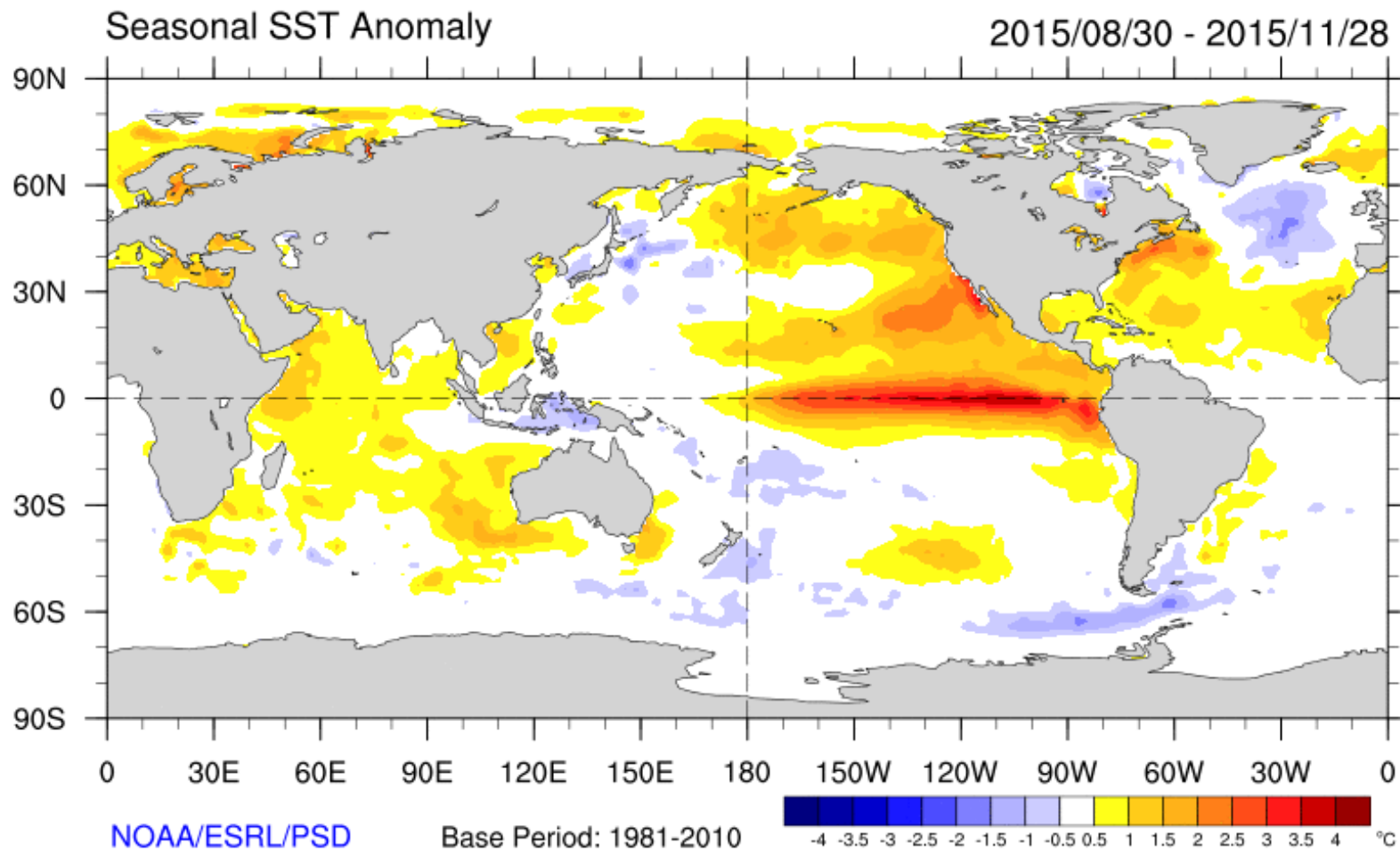
Office of Science

Biological and Environmental Research
Regional and Global Climate Modeling Program

When you say “Pacific climate” to most people, they often think “El Niño”



El Niño of 2015-2016—largest on record



December - February

Wet

Warm

Wet & Cool

Wet

Dry

Wet & Warm

Dry

Warm

Wet

Wet

Dry & Warm

Warm

Wet

NWS/INCEP
CLIMATE PREDICTION CENTER

90-Day Average OLR Anomaly

2015/09/03 - 2015/12/01

90N
60N
30N
0
30S
60S
90S

0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0

NOAA/ESRL/PSD Base Period: 1981-2010

-45 -35 -25 -15 -5 5 15 25 35 W m⁻²

Wet

Dry

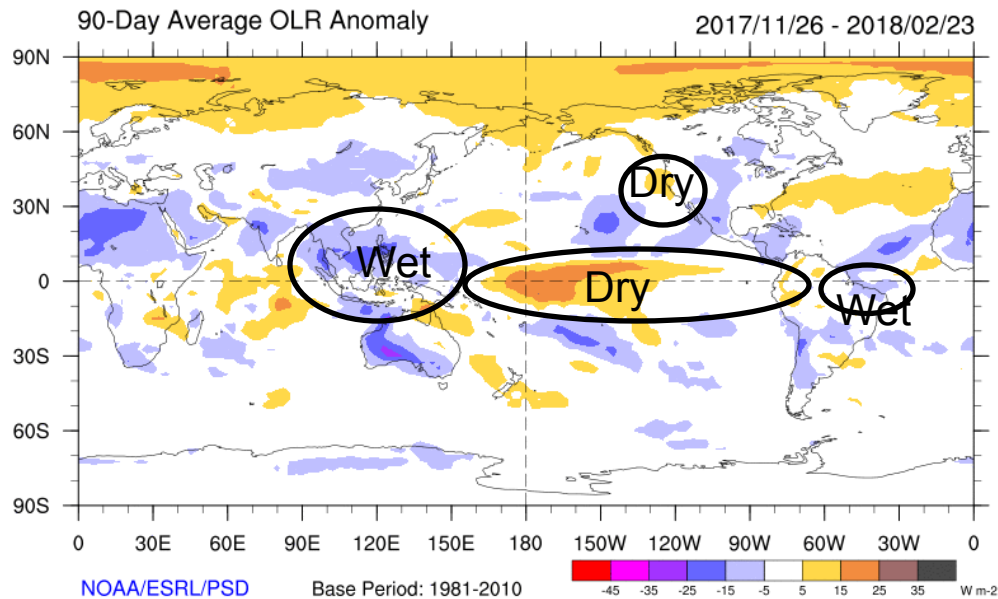
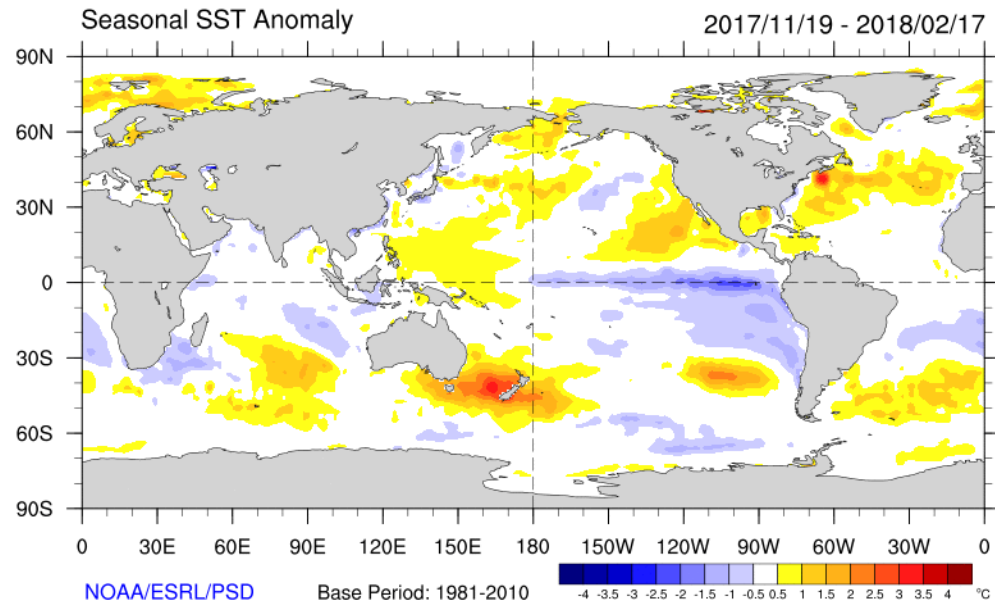
Wet

Dry

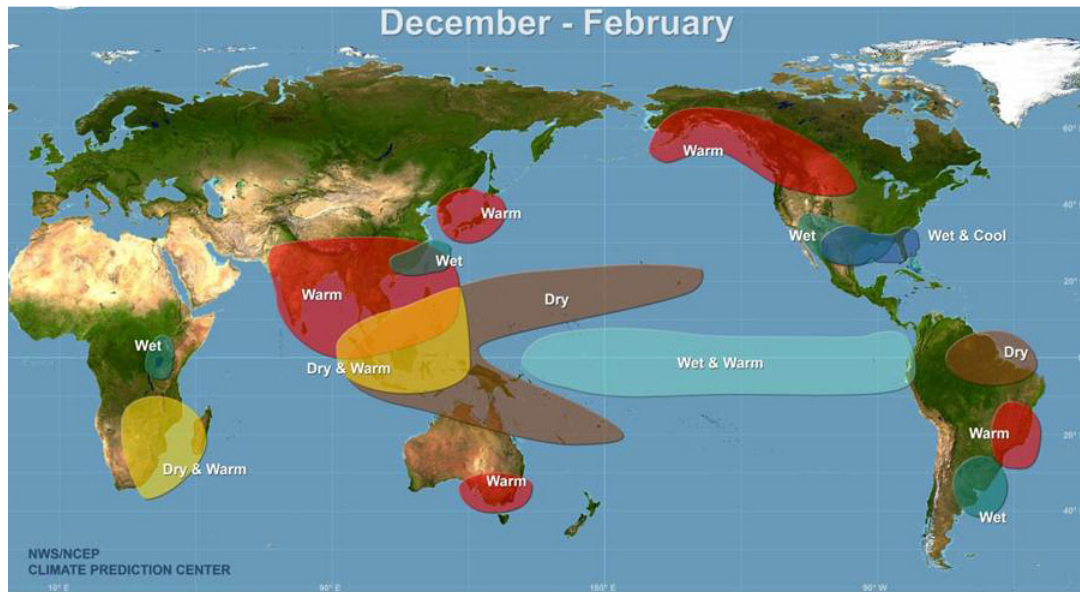
Wet

The flip side of El Niño is “La Niña”

The weak La Niña of 2017-2018 with nearly opposite impacts to El Niño



El Niño impacts



The future: As average ocean temperatures continue to warm, the impacts from El Niño events will worsen

Coral Bleaching

corals expel symbiotic algae that live and photosynthesize within their tissues



CORAL BLEACHING

Have you ever wondered how a coral becomes bleached?

HEALTHY CORAL

1 Coral and algae depend on each other to survive.



STRESSED CORAL

2 If stressed, algae leaves the coral.



BLEACHED CORAL

3 Coral is left bleached and vulnerable.



WHAT CAUSES CORAL BLEACHING?



Change in ocean temperature

Increased ocean temperature caused by climate change is the leading cause of coral bleaching.



Runoff and pollution

Storm generated precipitation can rapidly dilute ocean water and runoff can carry pollutants — these can bleach near-shore corals.



Overexposure to sunlight

When temperatures are high, high solar irradiance contributes to bleaching in shallow-water corals.



Extreme low tides

Exposure to the air during extreme low tides can cause bleaching in shallow corals.

Coral bleaching in progress in 2015 at Pago Pago, American Samoa



In Hawaii, bleaching occurred in Kaneohe Bay, Waimanalo on Oahu and Olowalu on Maui. On the Big Island, bleaching was reported from Kawaihae to South Kona on the leeward side and Kapoho in the southeast



"A mile and a half of reef on the eastern side of Lisianski Island is essentially dead"

(900 miles northwest of Oahu)

**Courtney Couch,
Hawaii Institute of Marine Biology**



Not all reefs that bleach die, but mortality of bleached reefs can be 50% or more



A reef in American Samoa

Mapping the Global Coral Reef Bleaching Crisis

The longest and most widespread global coral bleaching event on record began in 2014, causing reefs near at least 38 countries and island groups to turn ghost white— and in some cases killing them. The bleaching is ongoing, triggered by high ocean temperatures, and scientists say 38 percent of reefs have already been impacted. The Great Barrier Reef and reefs around Kiribati are among the hardest hit. The worst is likely yet to come for the Caribbean and Florida.

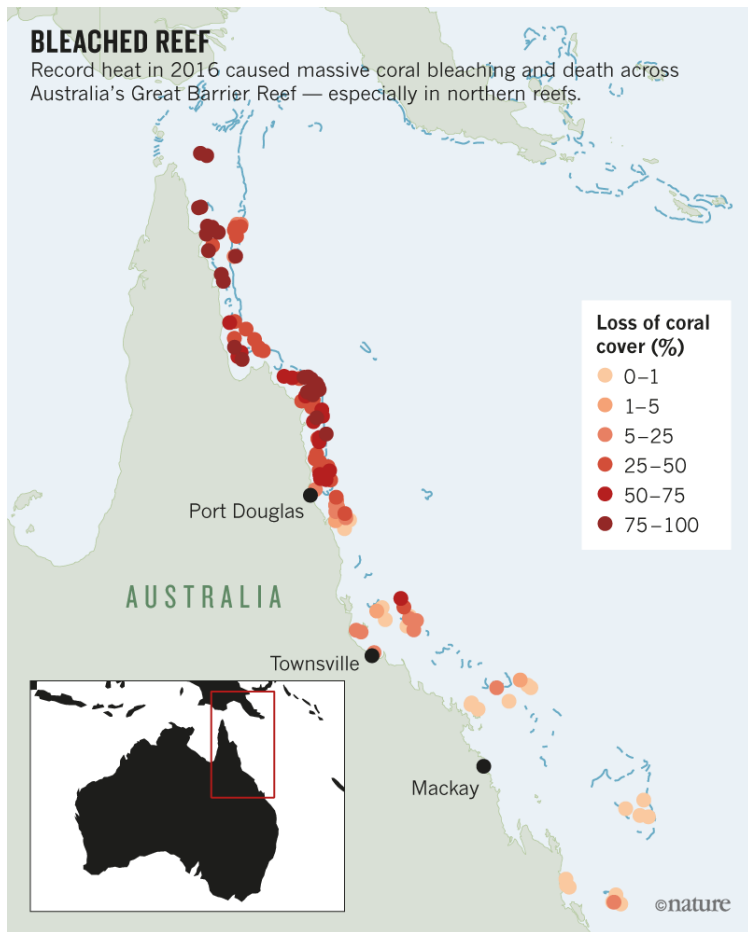


In 2015-2017, the Great Barrier Reef experienced its worst bleaching event on record

Bleaching during the 2015-2016 El Niño was severe and, for the first time, continued into the non-El Niño year of 2017

<https://www.facebook.com/chasingcoral/videos/1776577129313083/>

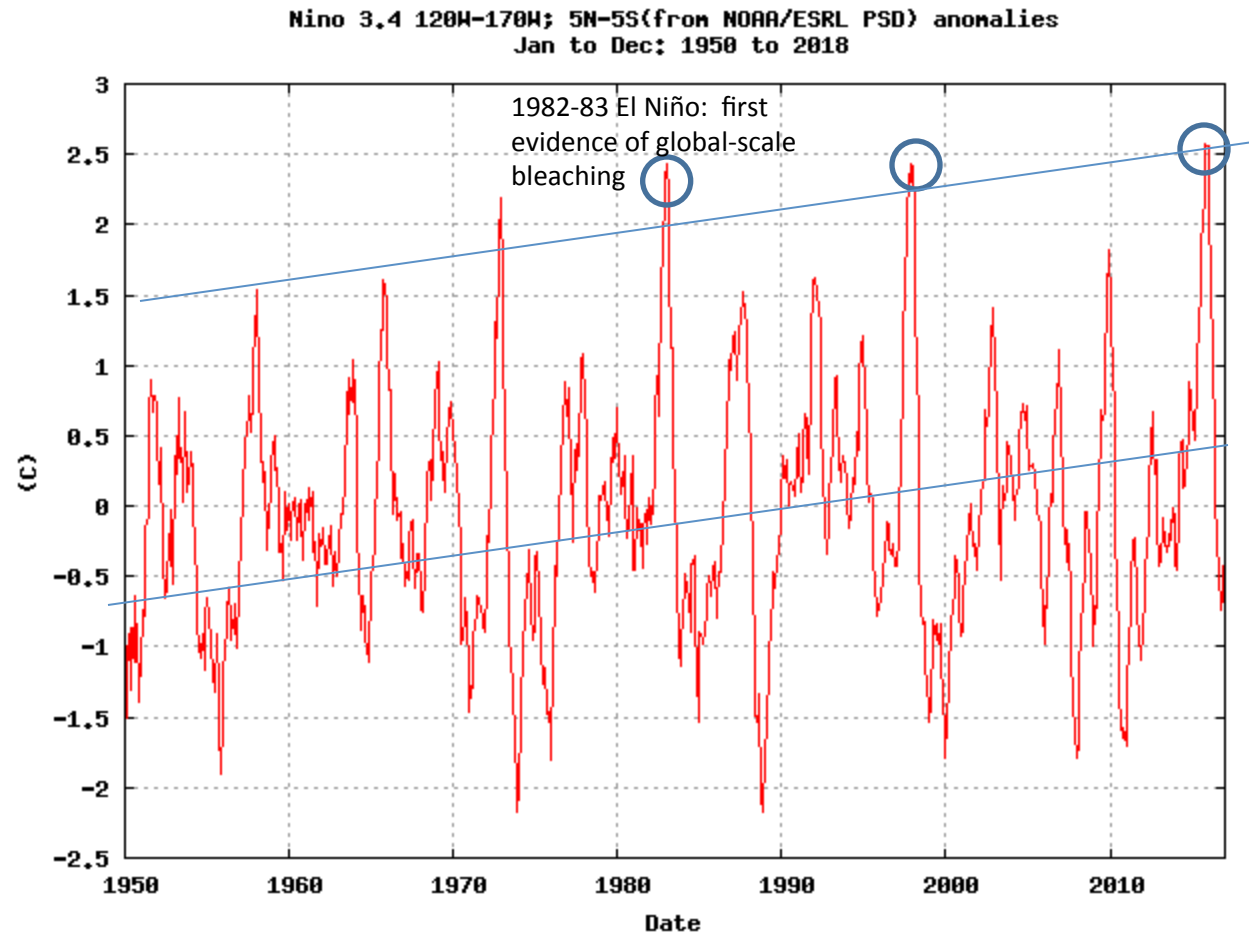




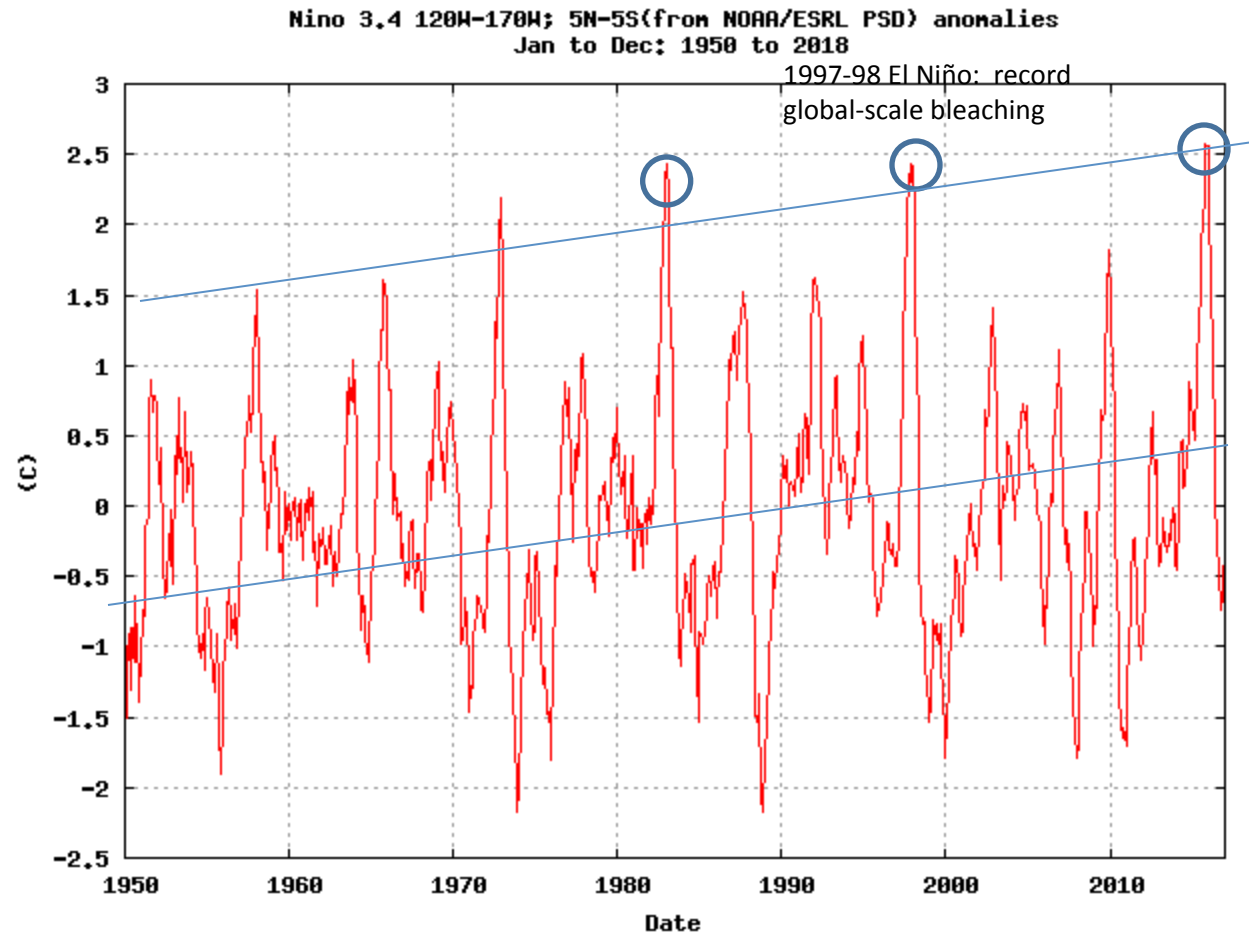
High ocean temperatures killed roughly 30% of the Great Barrier Reef corals in 2016 alone (Hughes et al., 2018, Nature)

“the interval between recurrent bouts of coral bleaching is too short for a full recovery...tropical sea surface temperatures are warmer now during current La Niña conditions than they were during El Niño events three decades ago. Consequently, as we transition to the Anthropocene, coral bleaching is occurring more frequently in all El Niño–Southern Oscillation phases, increasing the likelihood of annual bleaching in the coming decades.” (Hughes et al., 2018, Science)

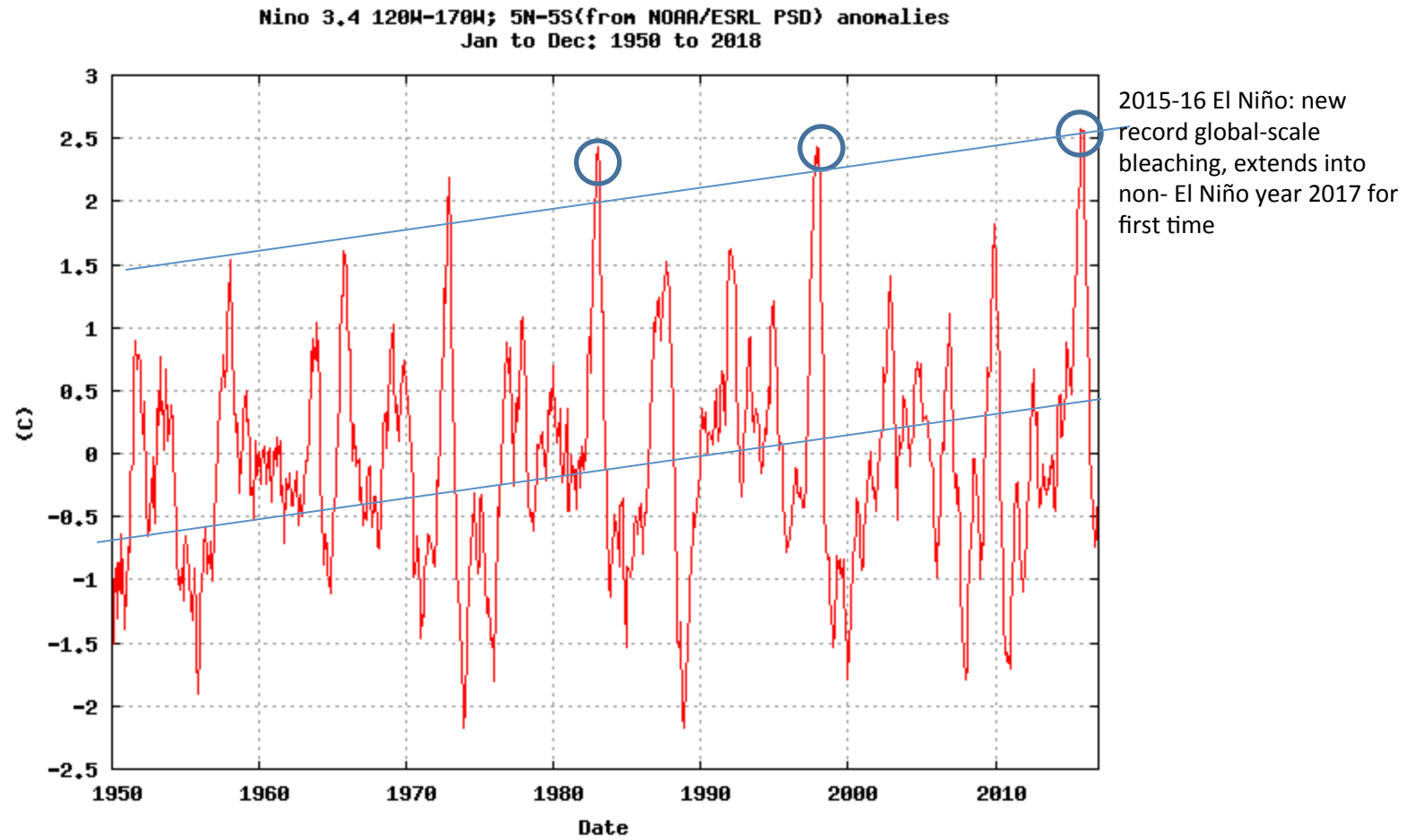
The El Niño connection: as average ocean temperatures warm, El Niño events are superimposed on those warmer temperatures and impacts become more severe



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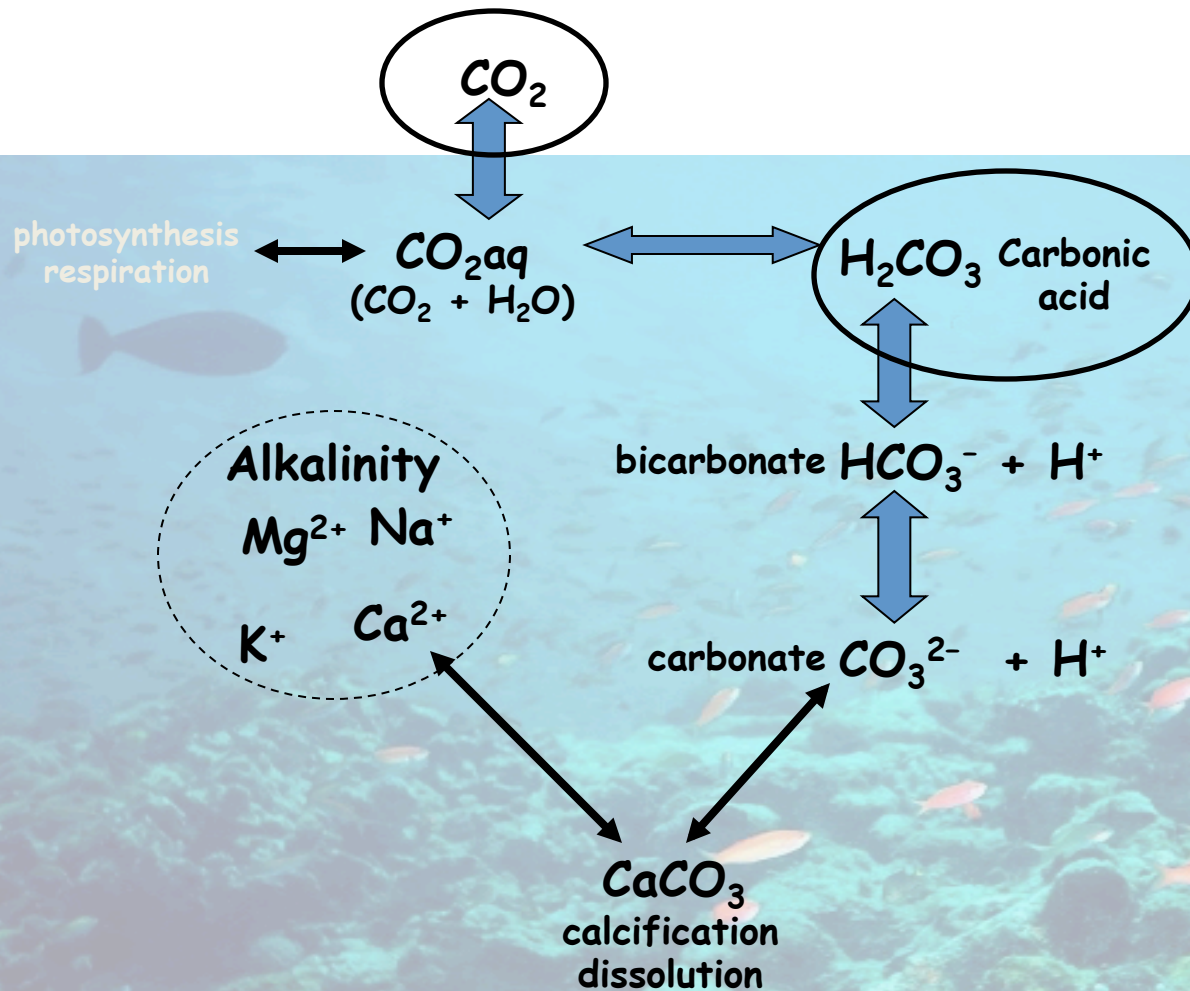


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Ocean Acidification and Carbonate Chemistry

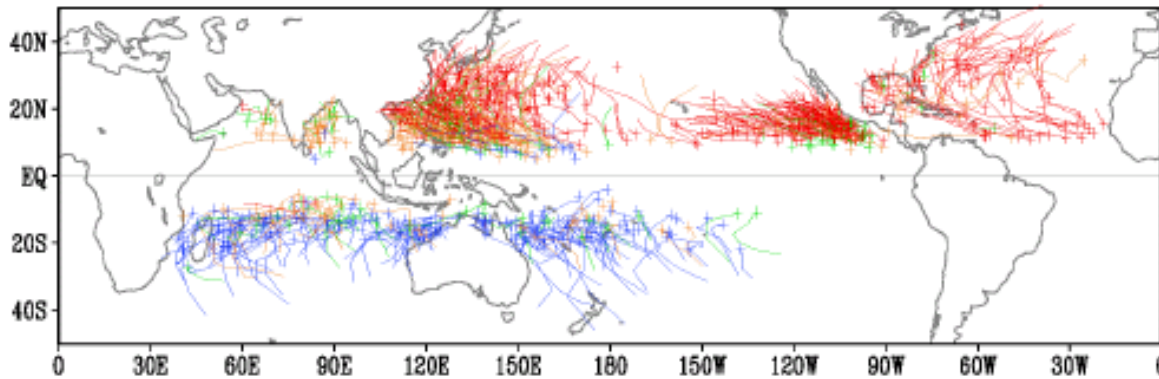
Causes skeletal loss in corals and other marine organisms



As CO_2 in the atmosphere increases from the burning of fossil fuels, the oceans become more acidic

Observation 1979–1988

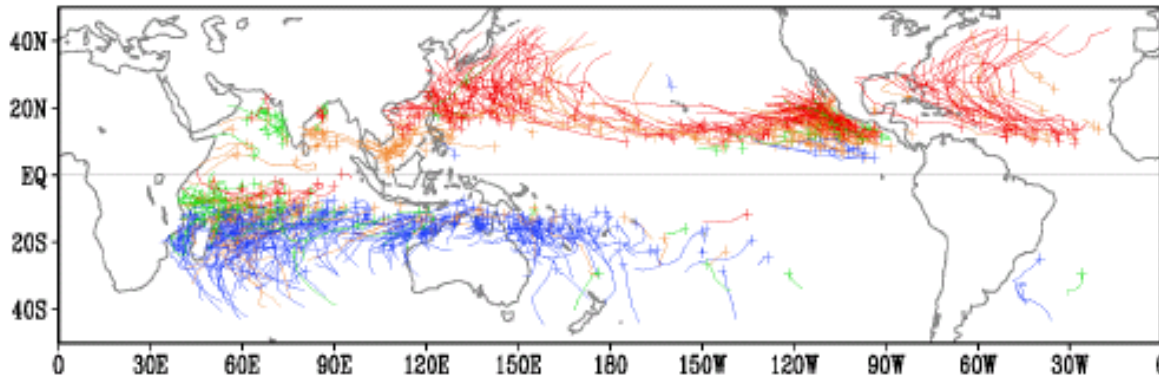
10 years



**Tropical cyclones/
typhoons
(hurricanes)**

Present-day expt.

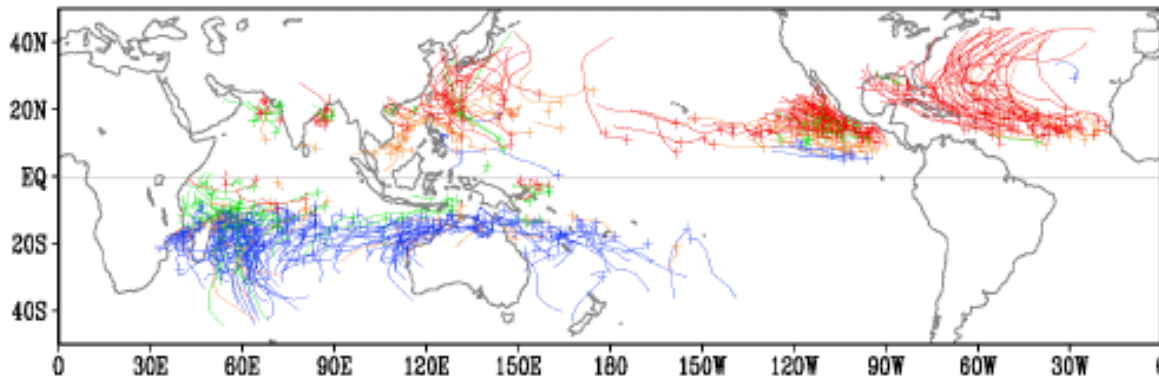
10 years



Hurricane tracks
from a global climate
model

Future expt.

10 years



**Future: less
hurricanes but the
ones that form will
likely be more
intense**

What about sea level rise?

Two factors can cause sea level to rise:

1. thermal expansion of warmer water
2. additional water added to the oceans from melting land ice (glaciers and ice sheets);

(sea ice is shrinking but that doesn't add to sea level rise)

What if you live on an atoll like this one? (Tetiaroa, highest point above sea level: 6 feet)
You'd better worry about land glaciers, Greenland and Antarctica!





Sea level rise over the past 50 years or so (about 8") is already causing coastal and beach erosion, increased tidal flooding, and more severe storm surge flooding; in the future sea level rise could submerge entire atolls making them uninhabitable



Coastal flooding on Funafuti Atoll (top) and Tarawa Atoll (bottom)



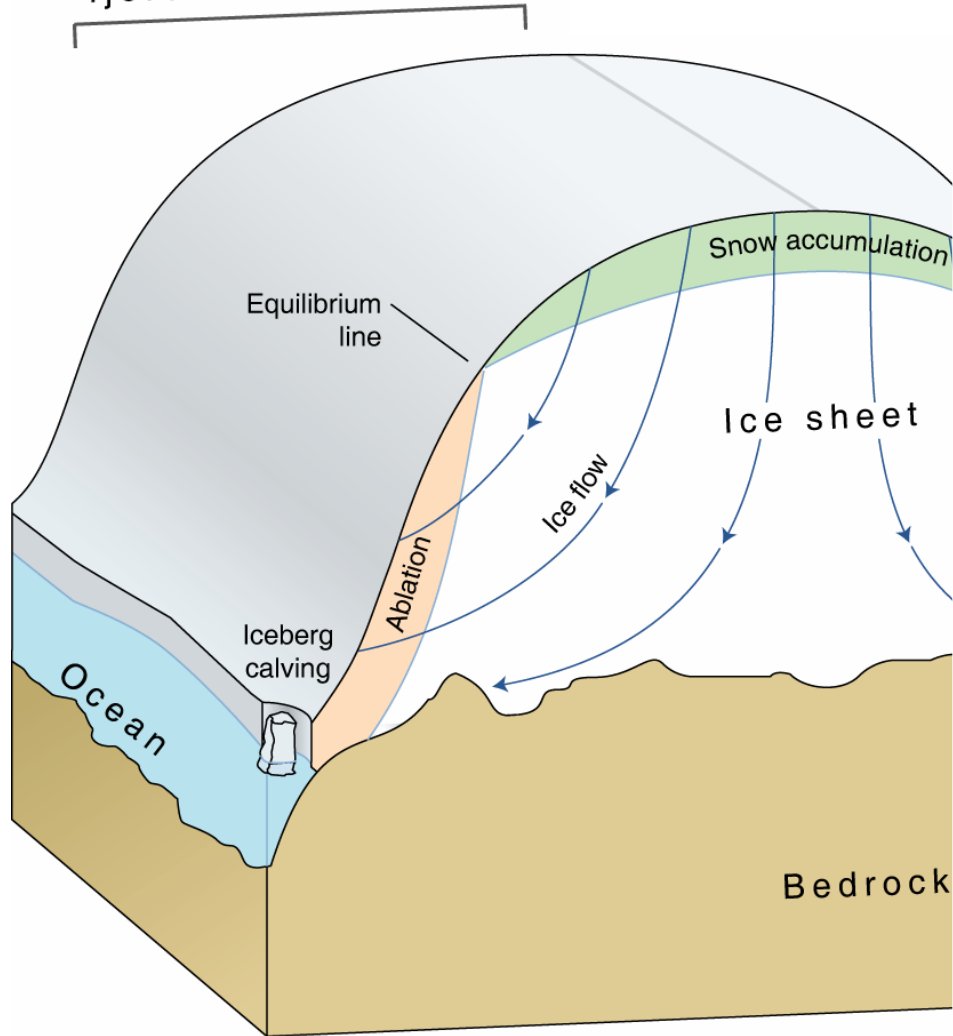
Melting all of the current Greenland ice sheet would result in a sea-level rise of about 6.5 meters (about 20 feet); melting all of the West Antarctic ice sheet would result in a sea-level rise of about 8 meters (about 25 feet)

This is not likely to happen, but accelerated melting of the Greenland ice sheet has already been observed

how much will melt and how fast?

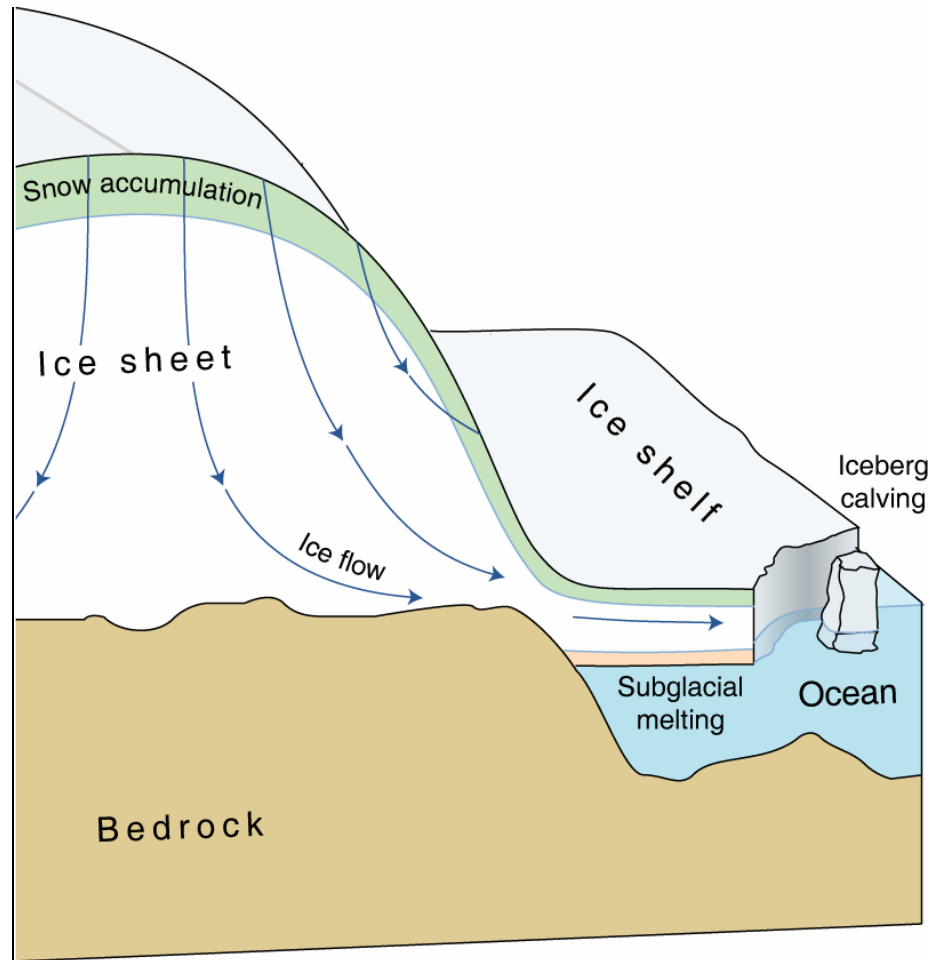
Greenland

Melting on the lower parts of the surface, icebergs calve off from ice sheet edges into ice fjords and the sea

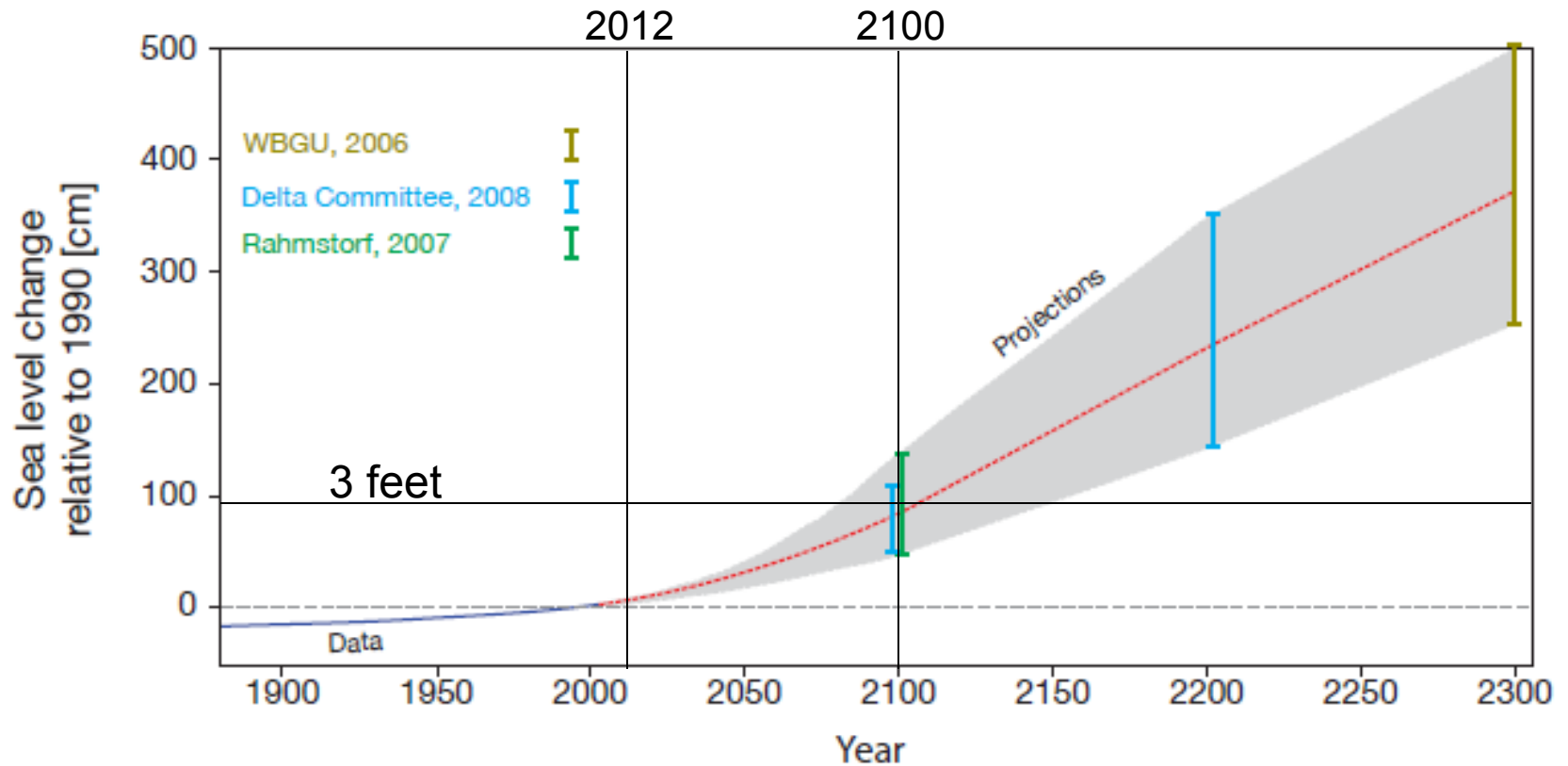


Antarctica

Ice shelves, with
subglacial melting.
Icebergs calve off
from ice shelves



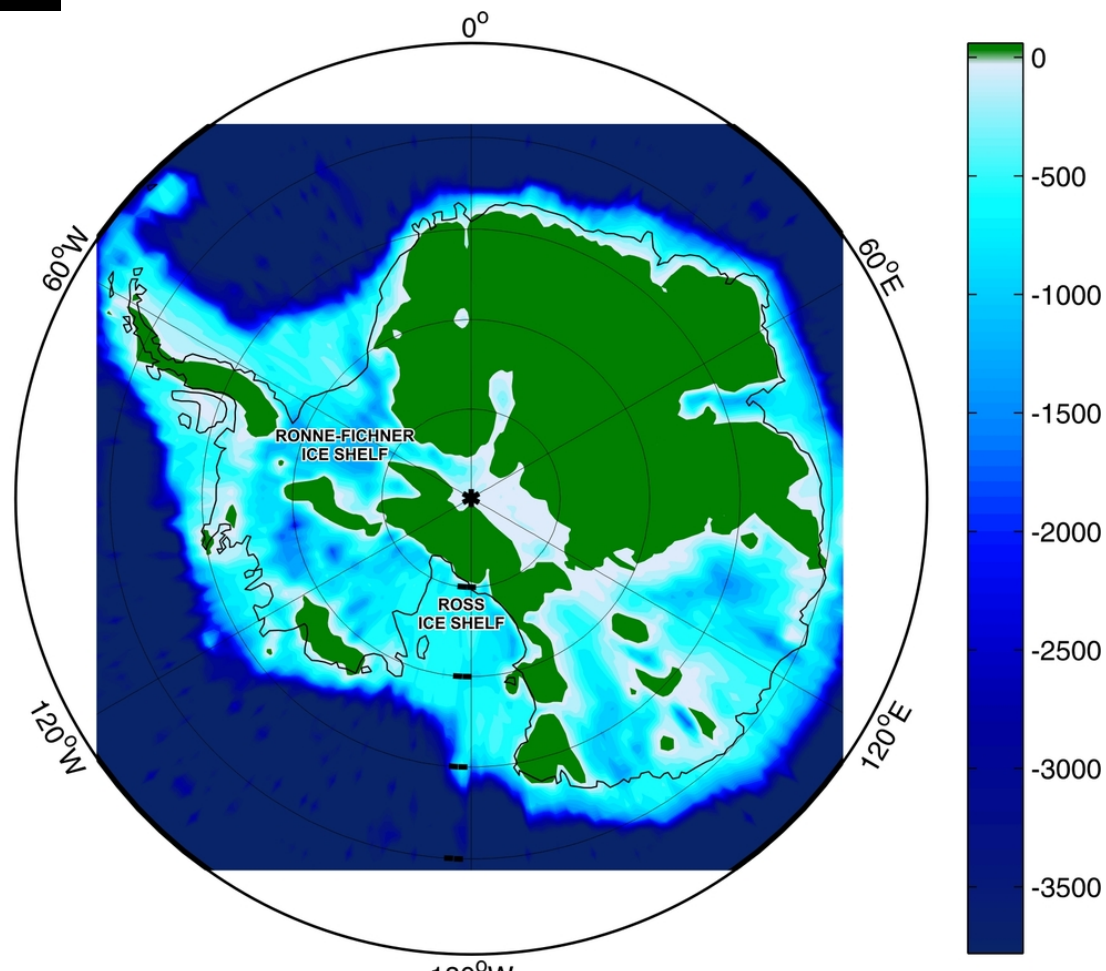
Due to our lack of knowledge of ice sheet disintegration processes, we still cannot definitively answer the questions “how much and how fast?” Some estimates go as high as 3 feet of sea level rise or more by 2100





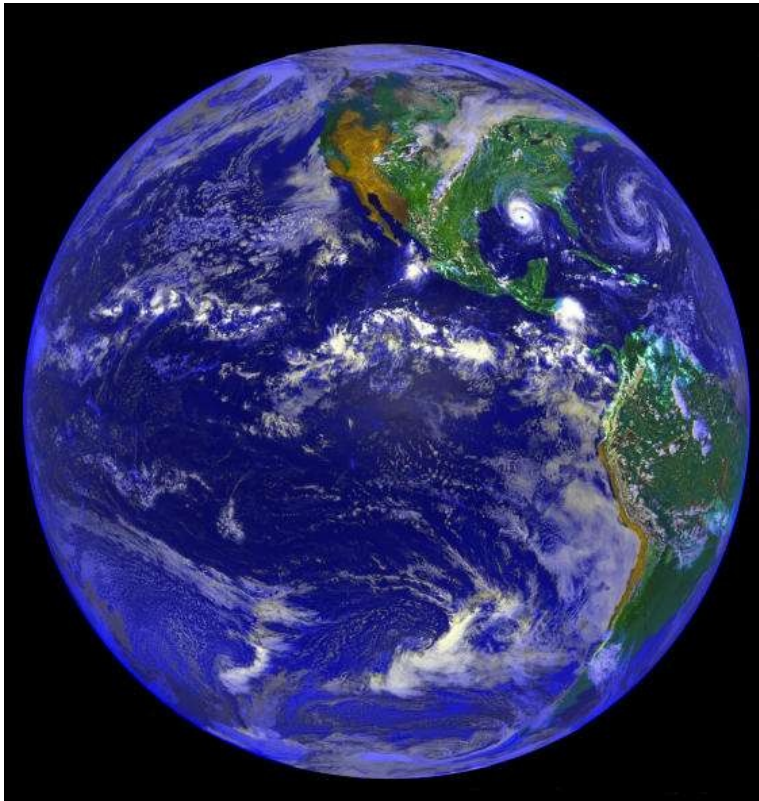
SCIENCEPHOTOLIBRARY

Much of West Antarctica is below sea level; if warming ocean water penetrates under the ice and starts melting it, the West Antarctic Ice Sheet could become unstable and disintegrate more rapidly—we have very little information on whether that has occurred before or could occur now

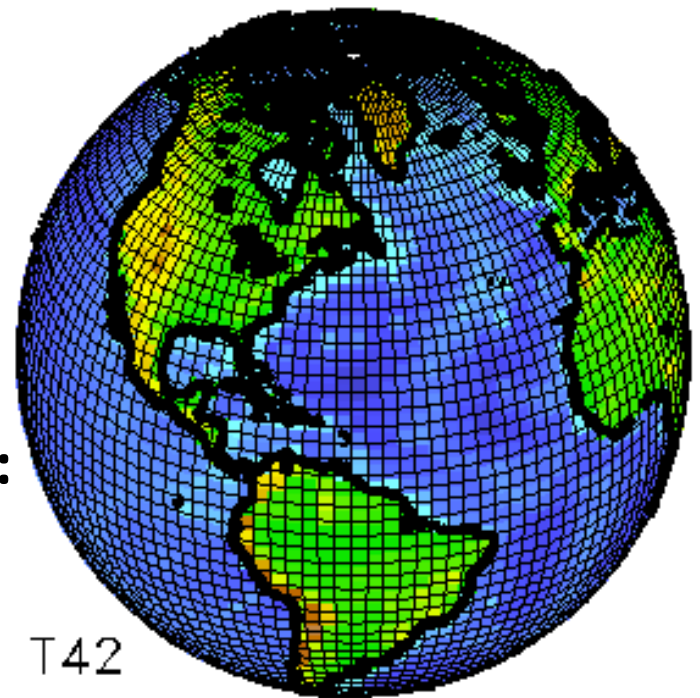


Earth System models

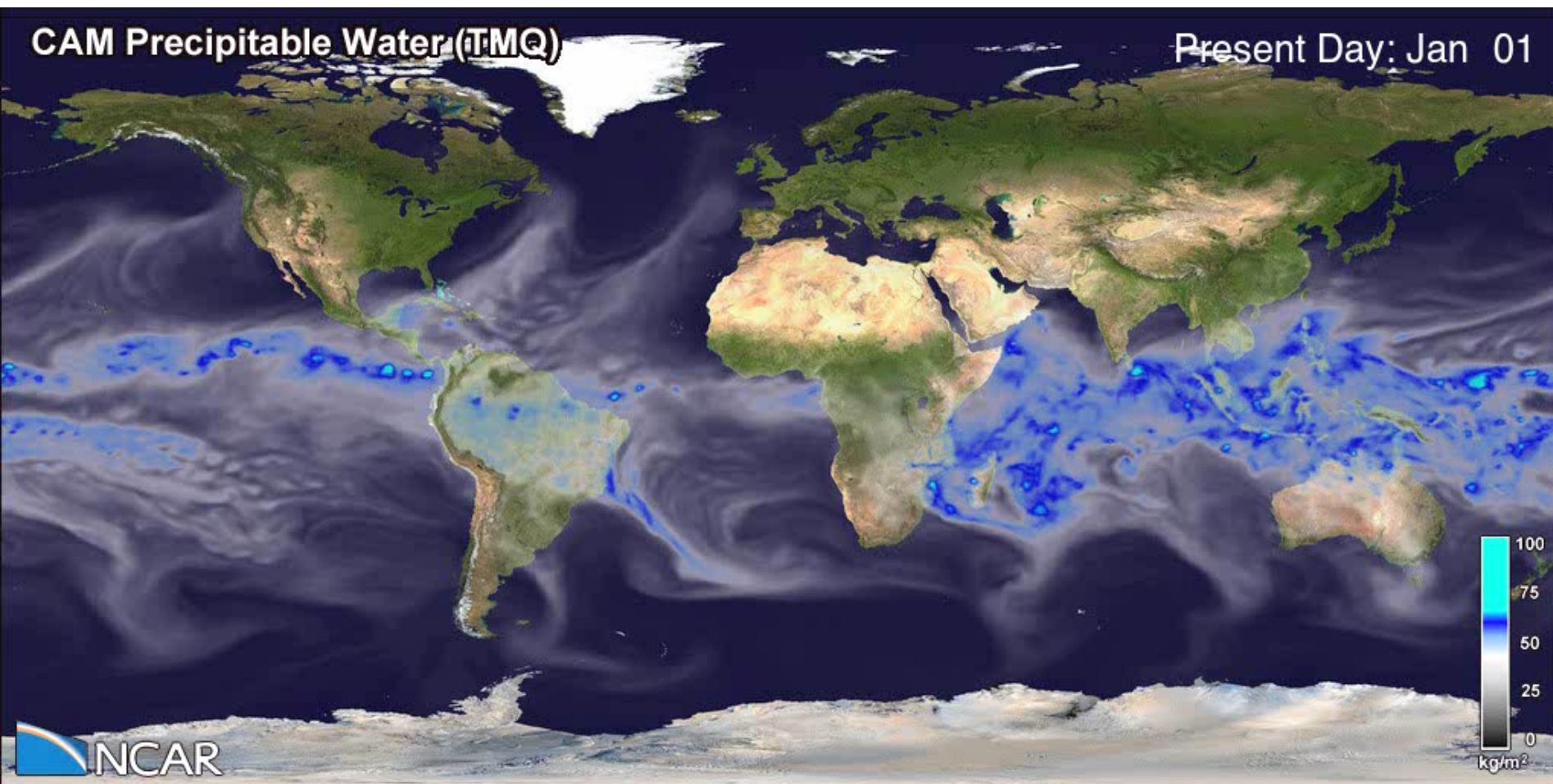
simulate this:



with this:



Components of atmosphere, ocean, land surface processes, sea ice, ice sheets (sea level rise), ocean biogeochemistry (ocean acidification), atmospheric chemistry (air pollution)



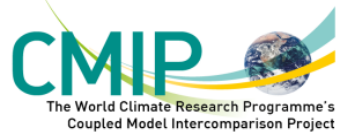
¼ degree (grid points every 25 km) time slice simulation representative of present-day climate run with an INCITE allocation at Argonne

Access and Analysis of Earth System Model output

current phase of CMIP6 expected to produce 10 petabytes of model data; 33 modeling groups from 16 countries
data access via web portals

Well-Established Analysis
Sharing of Diagnostic Code
Guidance and support from CMIP Panel,
WGNE/WGCM Climate Model Metrics
Panel and , CMIP6-Endorsed MIPs

Model Output



Processing Capability



Data Archive

Analysis computing environment integrated with the ESGF

Standardised Interfaces

Community-tools for Routine ESM Evaluation

Visualization & documentation
of evaluation results
Record of provenance
Scientific interpretation
Additional in-depth analysis

State evaluation of ECVs
(climatology, trends, ...)
Process and phenomena evaluation
Link to projections
(MMM analysis and emergent constraints)
Performance metrics



PCMDI Metrics Package (PMP)

Observations and Reanalyses



Summary:

Future threats to physical system in Pacific region related to increasing CO₂ from burning of fossil fuels:

1. Warming ocean temperatures produce more intense El Niño impacts (droughts, floods, extreme heat, coral bleaching)
2. Ocean acidification
3. Fewer total tropical cyclones/typhoons but more intense
4. Sea level rise
5. Earth System Models are tools to quantify possible future risks; large data volumes and distributed analysis via the Earth System Grid Federation

