# Global Warming & The Ocean

Princeton Primer- Climate and The Oceans

Chapter 7

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# Discussion Points

- Learn about the global temperature measurements.
- Learn about the main cause of global warming.
- Learn how global warming impacts the ocean.
- Tie our understanding of climate change to the present and future.

# Observed Temperatures

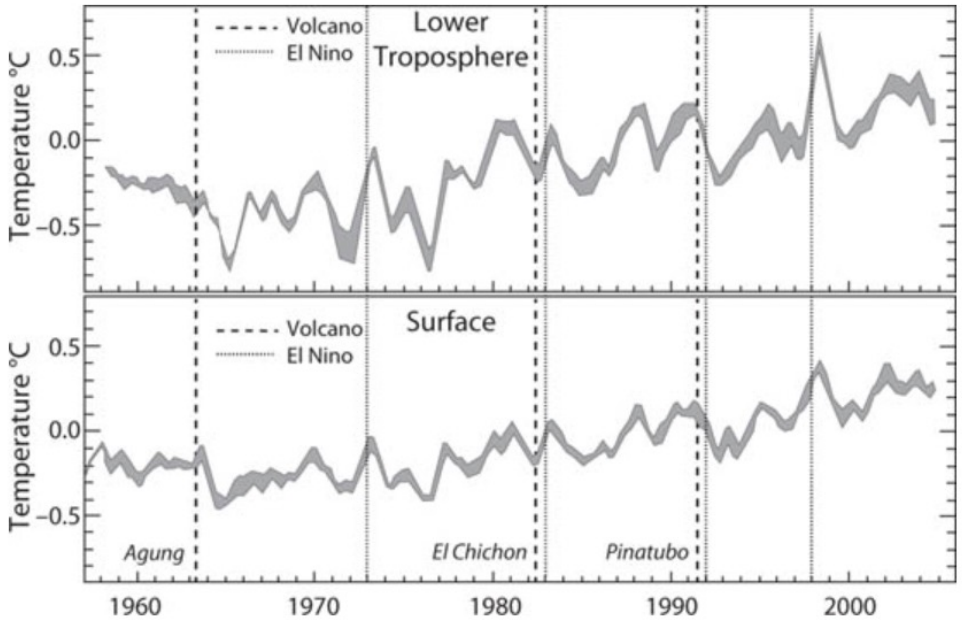



Figure 7.2. Top: Lower troposphere temperature as measured by various satellites and by radiosondes; the gray shading indicates the spread between all measurements. Bottom: Surface temperature records from NOAA, NASA, and UKMO, with gray shading again indicating the spread. Records are monthly means, smoothed with a seven-month running mean filter, and are relative to 1979–1997 mean. Adapted from Solomon et al., 2007.

Weather stations are primarily used to measure surface temperature, but satellite measurements can be used to support these measurements.



https://www.collinsdictionary.com/us/dictionary/english/stevenson-screen

# Global Temperature Measurements

Global Temperatures from the past can be measured indirectly using proxy data.

# Reconstructed Global Temperature Anamoly

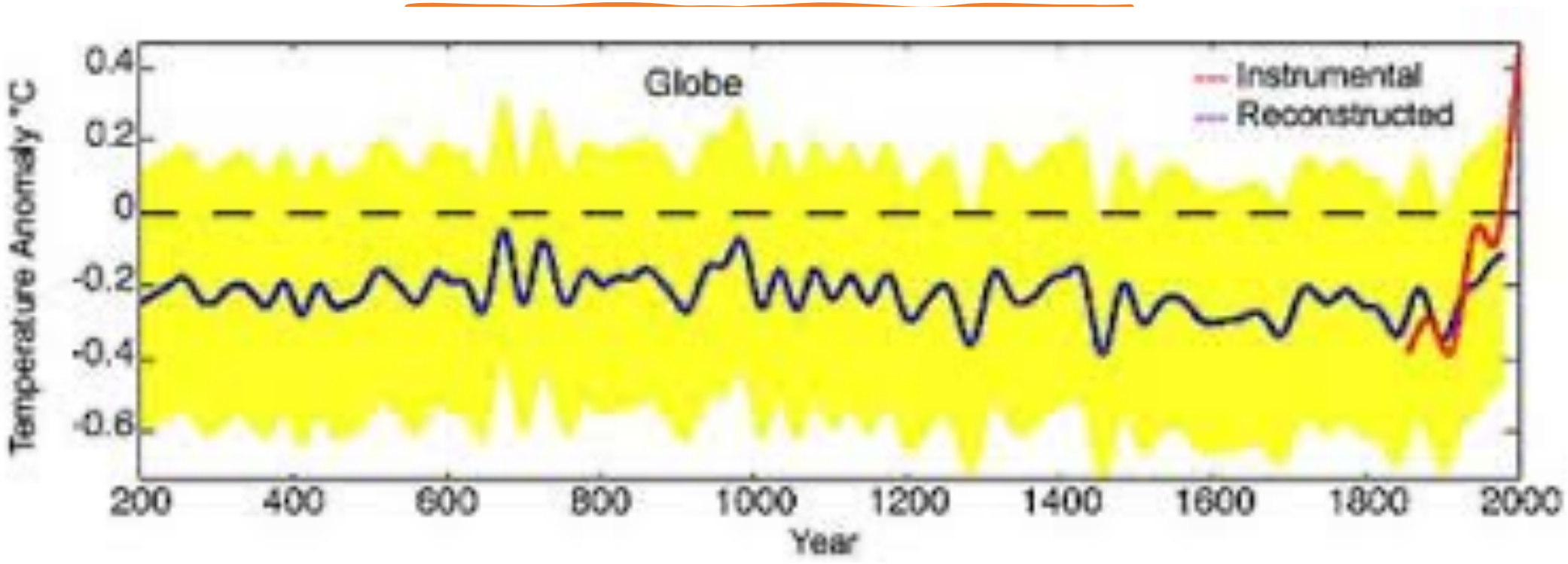


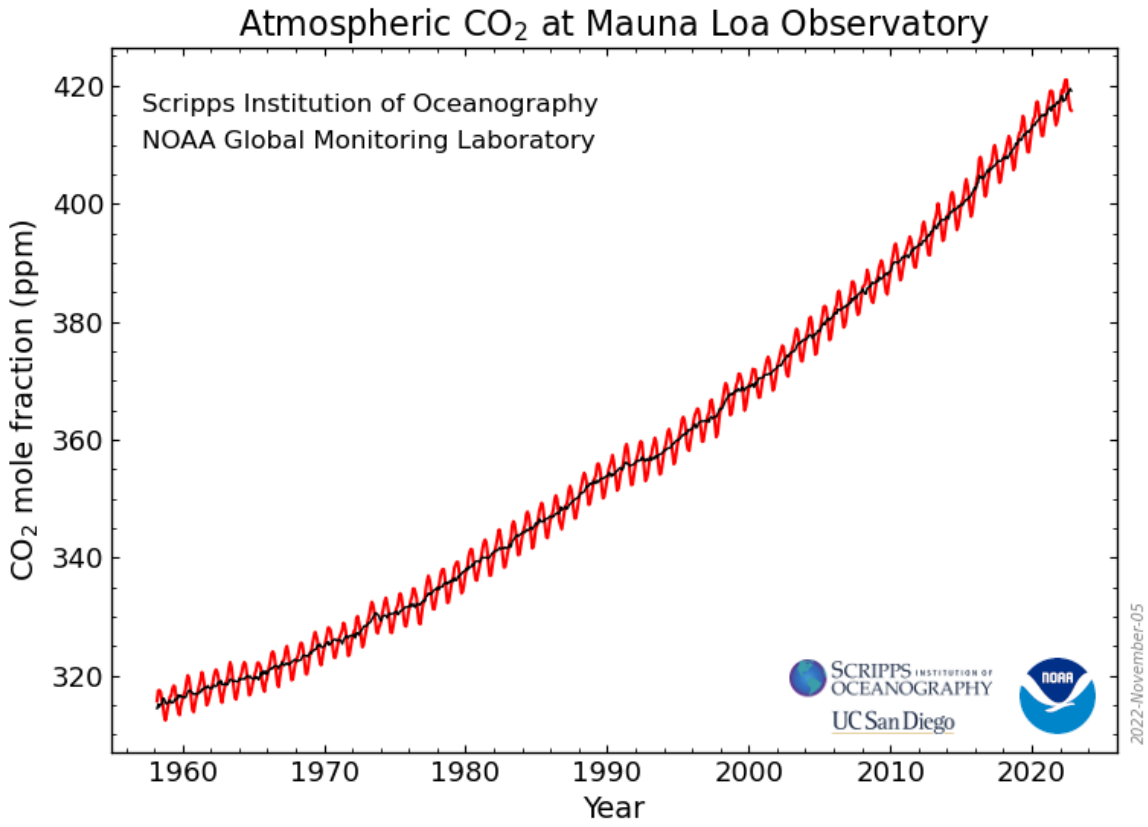

Figure 7.3. Global mean surface temperatures of the past 1,800 years. The lighter solid curve extending from about 1850 to 2000 shows the instrumental record. The longer solid curve is an estimate of temperature over the entire period using proxy reconstructions, and the gray shading is an error estimate (the 95 percent confidence interval). The series are smoothed to remove fluctuations of periods shorter than 40 years, and the temperatures represent anomalies in °C from a late twentieth century value.

Mann, M.E. and Jones, P.D.☐ 2003.☐ Global surface temperatures over the past two millennia.☐ *Geophysical Research Letters* **30**: 10.1029/2003GL017814.

# Where do humans enter?

Images From;
https://www.nbcnews.com/science/environment/fossil-fuel-plans-far-overshoot-climate-goals-study-finds-rcna3381
https://wordpressua.uark.edu/sustain/3-reasons-we-are-still-using-fossil-fuels/

# How do we know it's human driven?




Legacy of Charles Keeling, Scripps Institution of Oceanography, La Jolla, CA
https://www.esrl.noaa.gov/gmd/webdata/ccgg/trends/co2_data_mlo.png

# Greenhouse Gases

- Add some greenhouse gas to the atmosphere (this then increases the emissivity and absorptivity of the atmosphere.)
- Total outgoing longwave radiation = Incoming solar radiation.
- Since the absorptivity has increased, the outgoing longwave radiation, on average, originates from the upper atmosphere.
- Still, the temperature at the upper atmosphere must stay the same so that total outgoing longwave radiation stays the same.
- Unless the vertical profile of temperature changes, the surface temperature must increase.

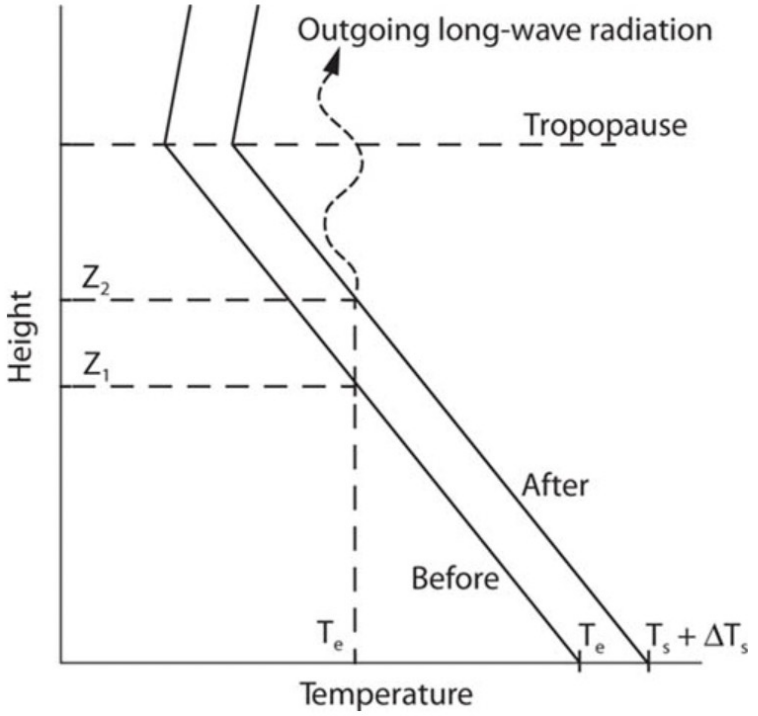



Figure 7.5. Schematic of temperature profiles before and after the addition of greenhouse gases. The total outgoing longwave radiation must remain the same because this radiation balances the incoming solar radiation, and so the emissions temperature, $T_e$, stays the same.

The vertical variations of the temperature change also have a climatic effect through the lapse-rate feedback $\lambda_L$. For instance, the models predict enhanced warming in the upper troposphere of tropical regions in response to an increase in the concentration of greenhouse gases. Because of this change in the lapse rate, the outgoing longwave radiation will be more than in an homogenous temperature change over the vertical. The system will then lose more energy, so inducing a negative feedback (Fig. 4.10). Moreover, at mid to high latitudes, a larger low level warming is projected as a response to the positive radiative warming, providing a positive feedback (Fig. 4.10). The global mean value of $\lambda_L$ thus depends on the relative magnitude of those two opposite effects. On average, the influence of the tropics dominates, leading to a value of $\lambda_L$ of around -0.8 $Wm^{-2}K^{-1}$ (Soden and Held, 2006) in recent models driven by a doubling of the $CO_2$ concentration in the atmosphere.

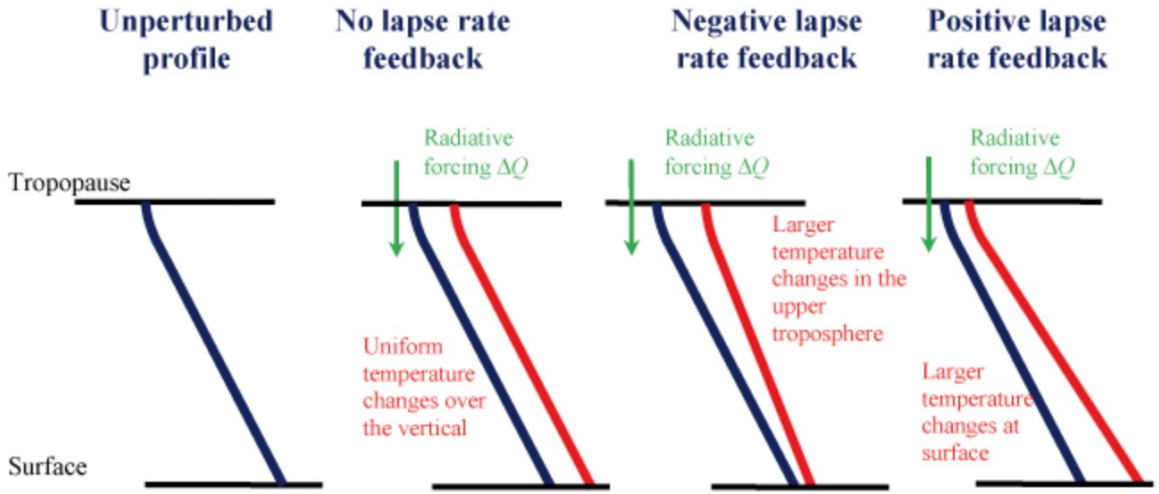



**Figure 4.10:** Schematic representation of positive and negative lapse-rate feedbacks.

The water-vapour feedback and the lapse-rate feedback can combine their effects. If the temperature increases more in the upper troposphere causing a negative lapse-rate feedback, the warming will also be associated with higher concentrations of water vapour in a region where it has a large radiative impact, leading to an additional positive water-vapour feedback. The exact changes in temperature and humidity at high altitude in response to a perturbation are not well-known. However, as the effects of the two feedbacks discussed in this sub-section tend to compensate each other, the uncertainty in the sum $\lambda_L + \lambda_W$ is smaller than in the feedbacks individually. This uncertainty is estimated at about 0.1 $Wm^{-2}K^{-1}$, the standard deviation of the values provided by the different models presented in the 4th IPCC assessment report (Randall et al., 2007).

http://www.climate.be/textbook/chapter4_node7.html

# Warming of the Ocean

Where is the ocean warming?

Upper several meters of the ocean.

$C_{total} = 10^{24}$ J/K

$A_{ocean} = 3.6 \times 10^{14}$ m$^2$

$C_{water} = 4 \times 10^3$ J kg$^{-1}$ K$^{-1}$

Heat content = $+ 15 \times 10^{22}$ J

$\Delta T = + 0.15°C$

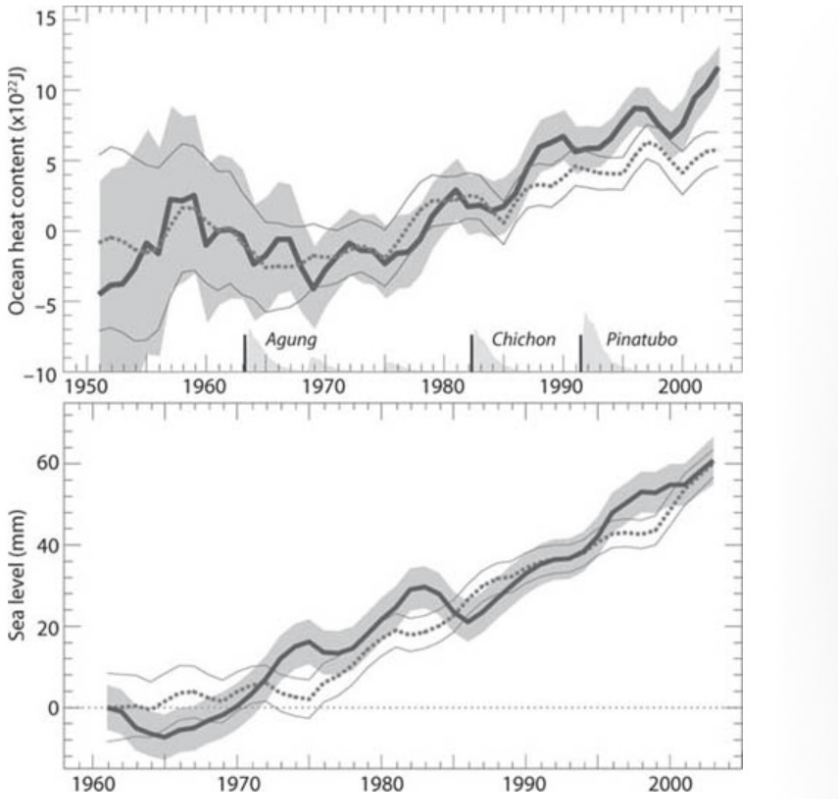
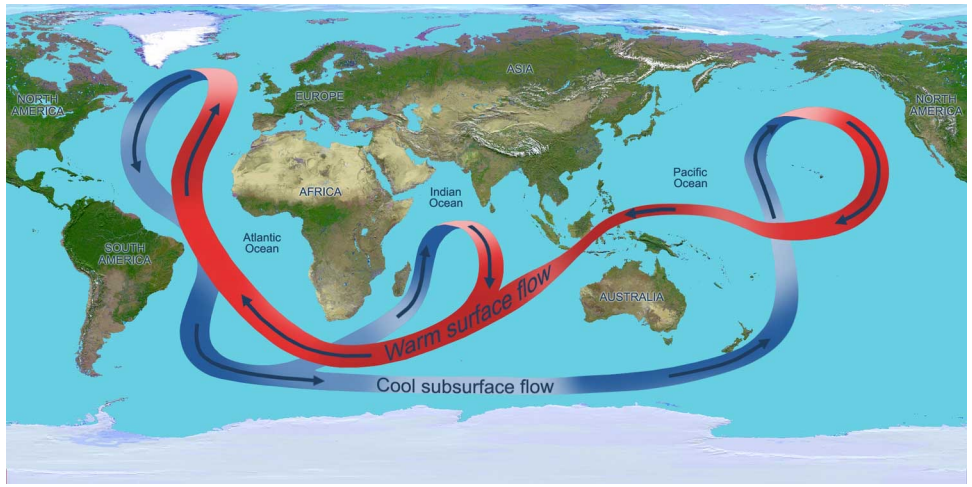
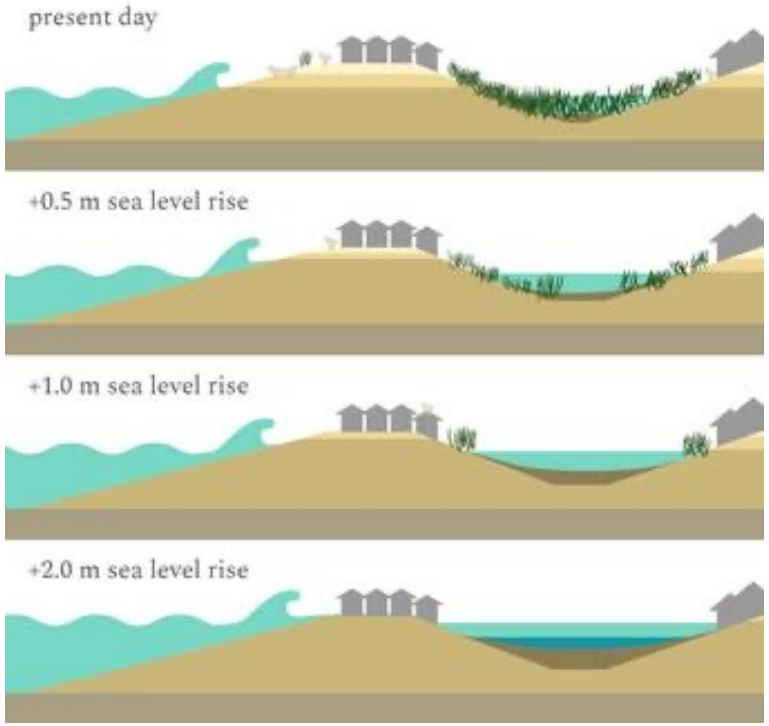



Figure 7.6. Top: The global heat content for the upper 700 m of the ocean (solidblack line, with shading indicating uncertainty) and upper 100 m of the ocean (dotted line, with thin solid lines indicating uncertainty). Bottom: Increase in sea level as estimated from direct measurements (black line and shading) and by combining the contributing components (dotted line and thin solid lines). The time series are all relative to 1961 and smoothed with a three-year running average. Source: Adapted from Domingues et al., 2008.

# How is the ocean impacted by global warming?

- Delay in equilibrium state
- The ocean circulation may be altered
- The sea level will rise




Images From; https://www.nature.com/articles/s41598-021-94942
https://www.rmets.org/metmatters/atlantic-meridional-- overturning-circulation
https://giphy.com/explore/ticking-clock

# The Slowing of Global Warming

- Add greenhouse gas

# What happens as the deep ocean warms?

- Eventually the mixed layer can give up less heat to the ocean below it.
- To balance the radiative forcing, the temperature of the mixed layer must increase, and heat gets added back to the atmosphere.

# What if $CO_2$ is doubled?

**Temperatures will increase roughly by 1.8°C.**

What if we then magically prevent greenhouse gases levels from increasing?

The estimates of the climate sensitivity given in this chapter are based on Meehl et al. (2007) and Padilla et al. (2011)

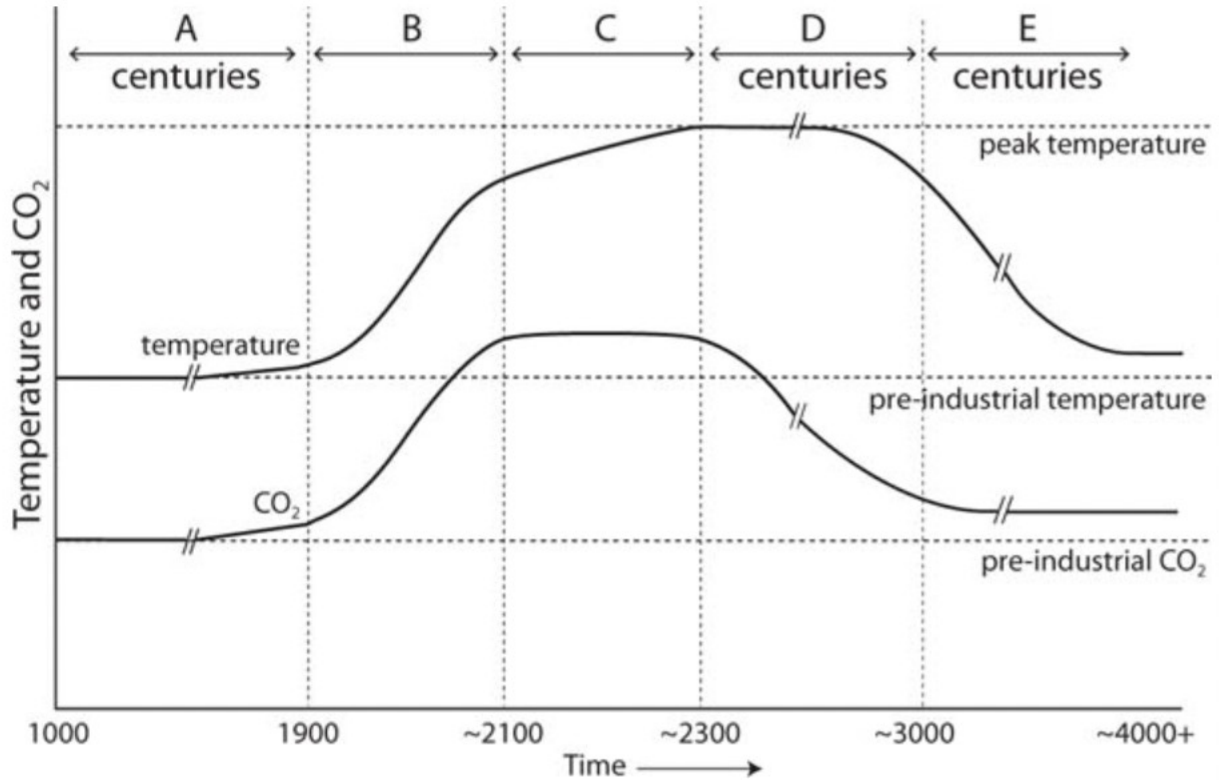
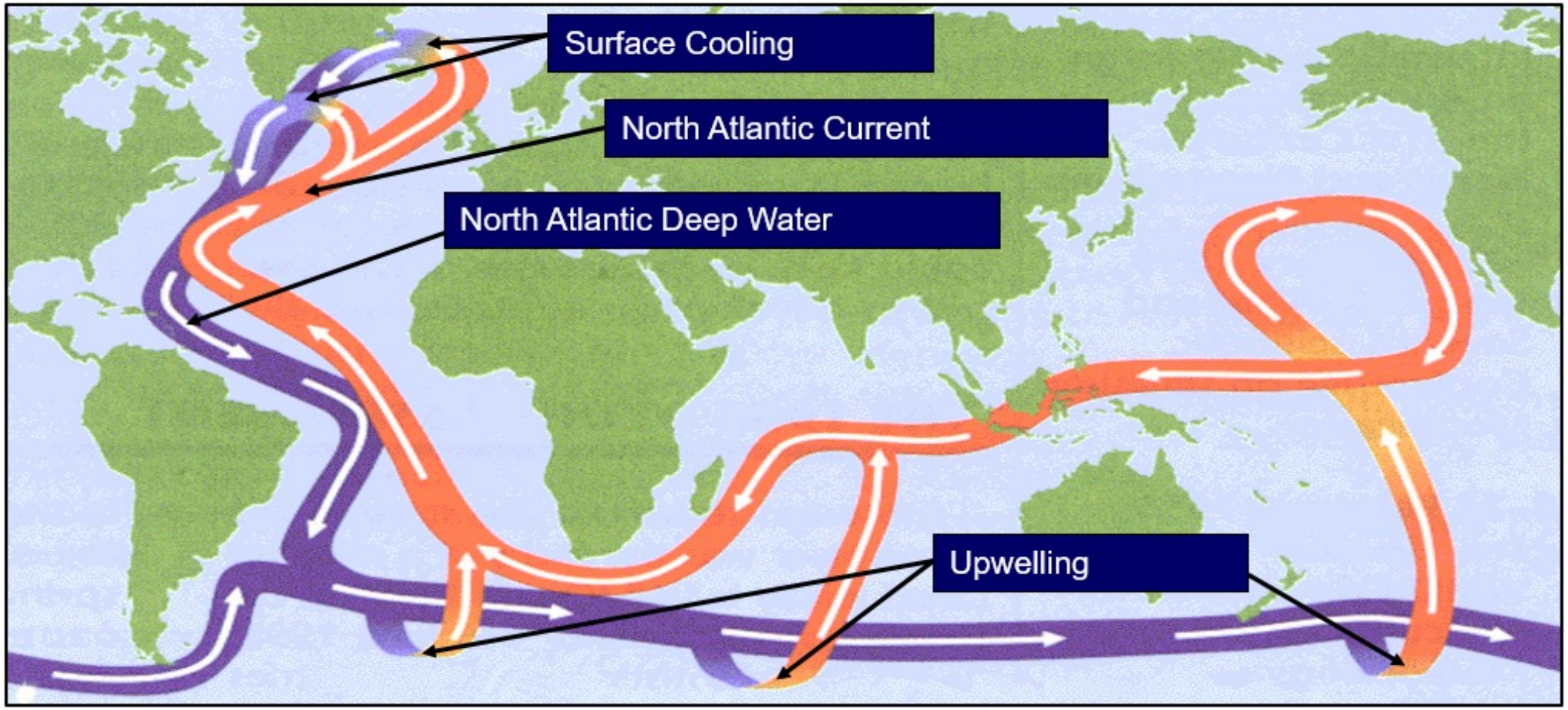



Figure 7.7. Schema of a $CO_2$-temperature scenario. Carbon dioxide levels increase from 1900 to 2100 (period B) before leveling off (period C) because of controls on emissions. Temperature increases rapidly in period B, then more slowly in period C. At the end of period C (the year 2300 in the figure), anthropogenic emissions go to zero, and the level of $CO_2$ slowly diminishes through periods D and E back to levels close to, but probably a little above, the preindustrial period. In period D, temperature stays roughly constant for centuries before it too eventually falls back to near pre-industrial levels in period E. Many plausible scenarios can be adapted from this plot by changing 2100 and 2300 to other dates and calibrating the *y*-axis.

# Circulation Changes

**Meridional Overturning Circulation**




https://www.carbonbrief.org/guest-post-could-the-atlantic-overturning-circulation-shut-down/

# Cessation in the Overturning Circulation

**How can the MOC come to a halt?**

# How likely is this?

A severe slowdown in the overturning circulation would mean that the ocean would transport less heat to high latitudes.

# Sea-Level Rise

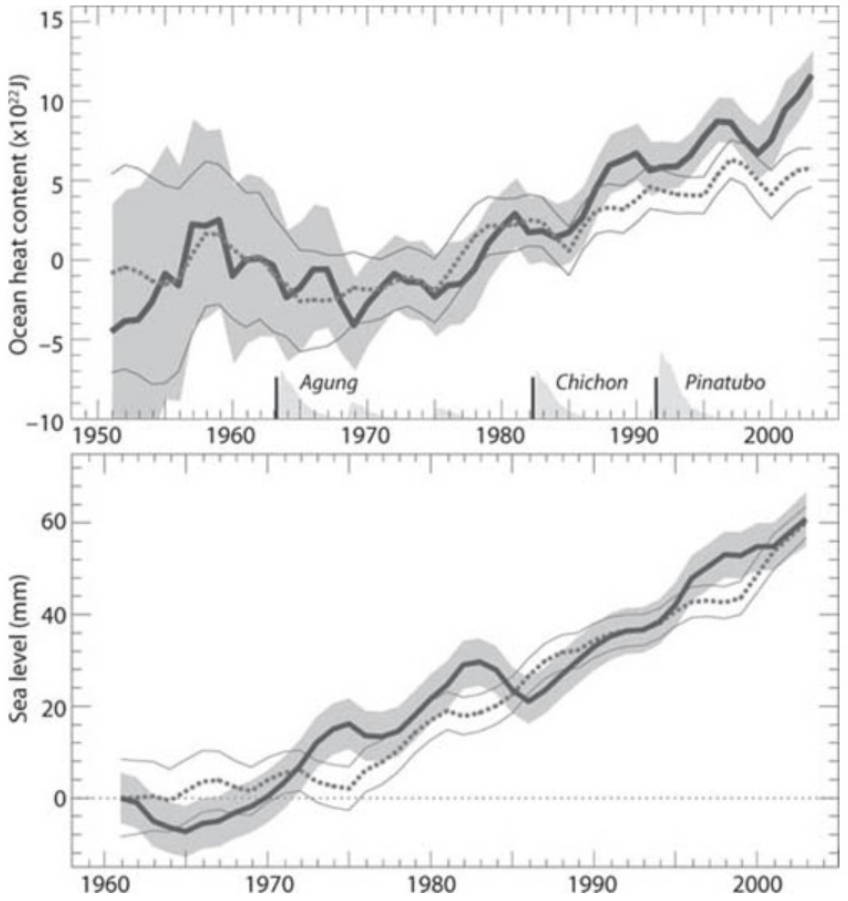
$$\frac{\Delta V}{V} = \beta_T \Delta T$$

**ΔV** is the change in volume,

**V** is the current volume,

**T** is the temperature,

**βT** is the coefficient of thermal expansion ($1.4 \times 10^4\ K^{-1}$ )

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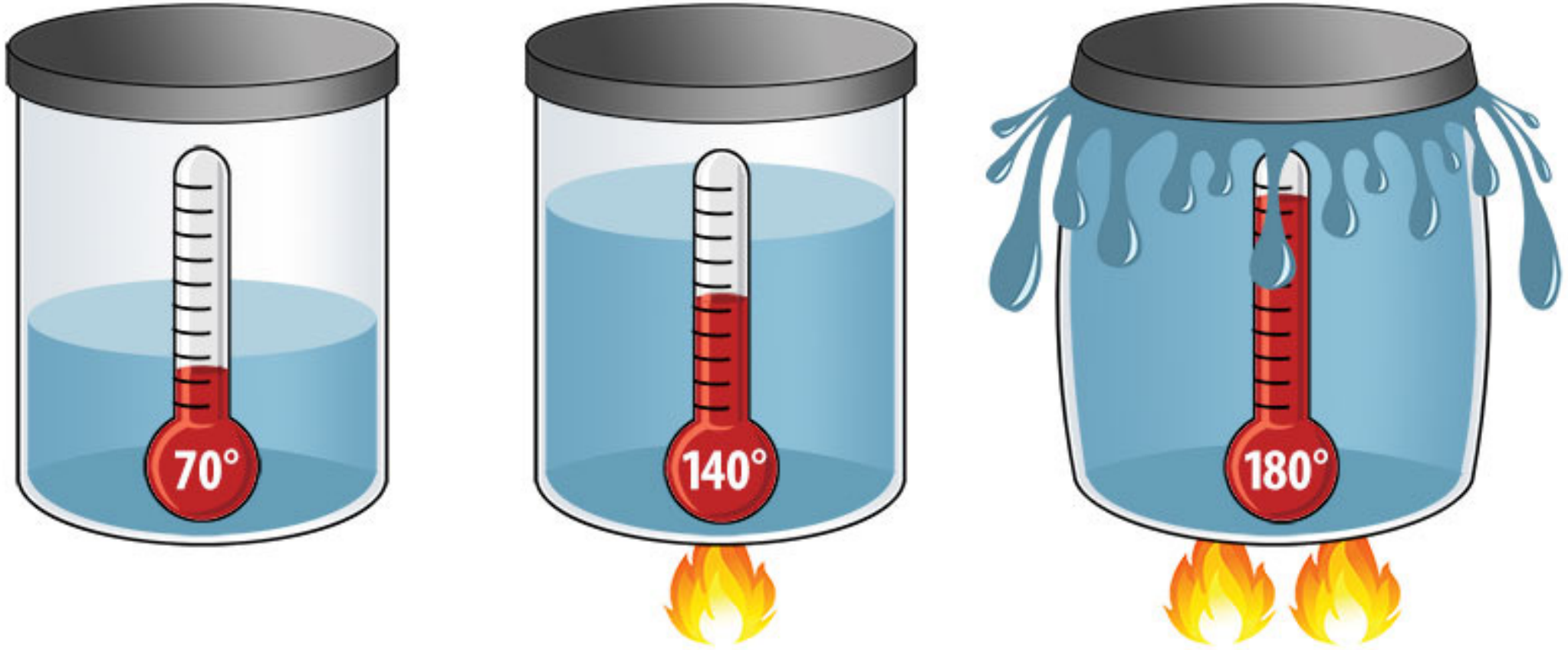
# Thermal Expansion and Sea Level Rise




https://www.plumbingsupply.com/thermal-expansion.html

# Sea-Level Rise

$$\frac{\Delta V}{V} = \beta_T \Delta T$$

**Scenario One:**

**V** → +3.7 km (depth of ocean)

**ΔT =** 1°C

**βT** = $1.4 \times 10^4\ K^{-1}$

Sea Level Rise ≈ 0.5m

**More realistic scenario:**

**V** → 1 km (upper ocean)

**ΔT =** 1°C

**βT** = $2.0 \times 10^4\ K^{-1}$

Sea Level Rise ≈ 0.2m

# Loss of Sea Ice & Land Ice

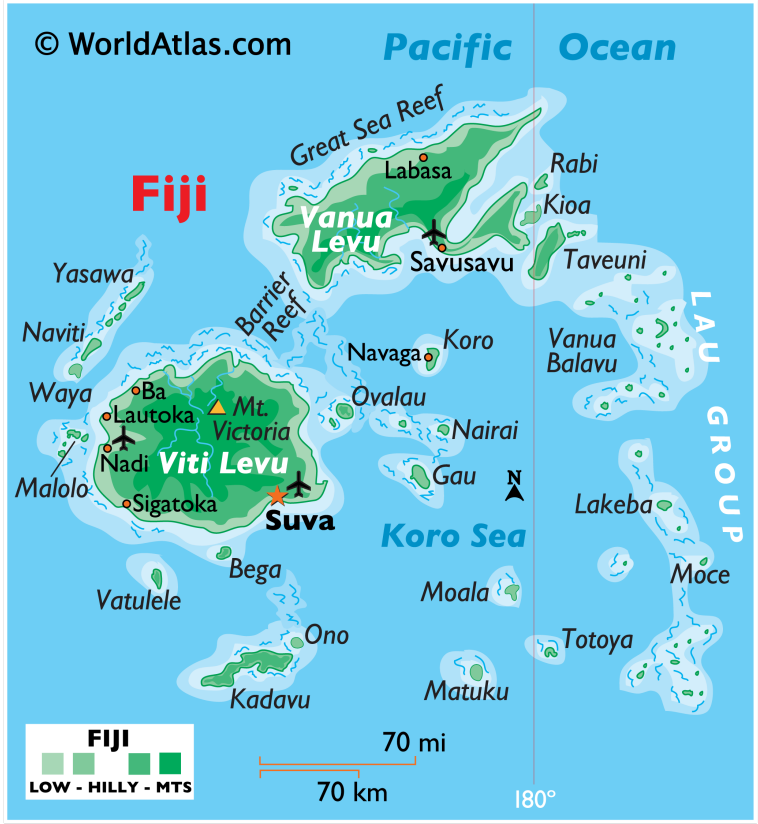
**What is main issue with the loss of sea ice?**

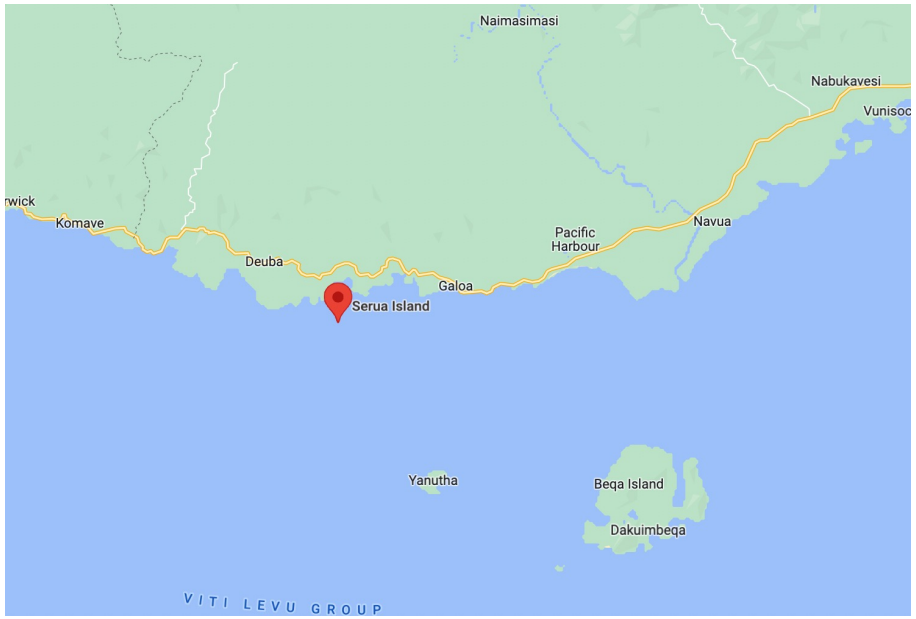
**What is main issues with the loss of land ice?**


https://www.youtube.com/watch?v=Kp5OqedXlGA

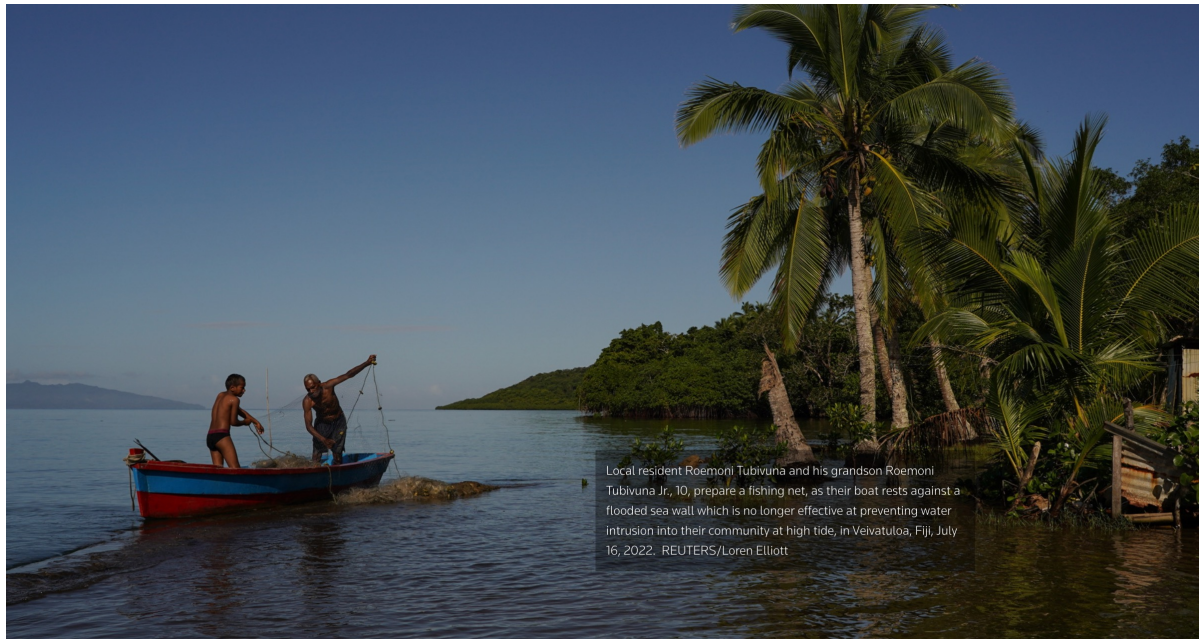
“ Global warming, once it has occurred, will persist for centuries”(p.208)

# Sea Level Rise Impacting Fiji

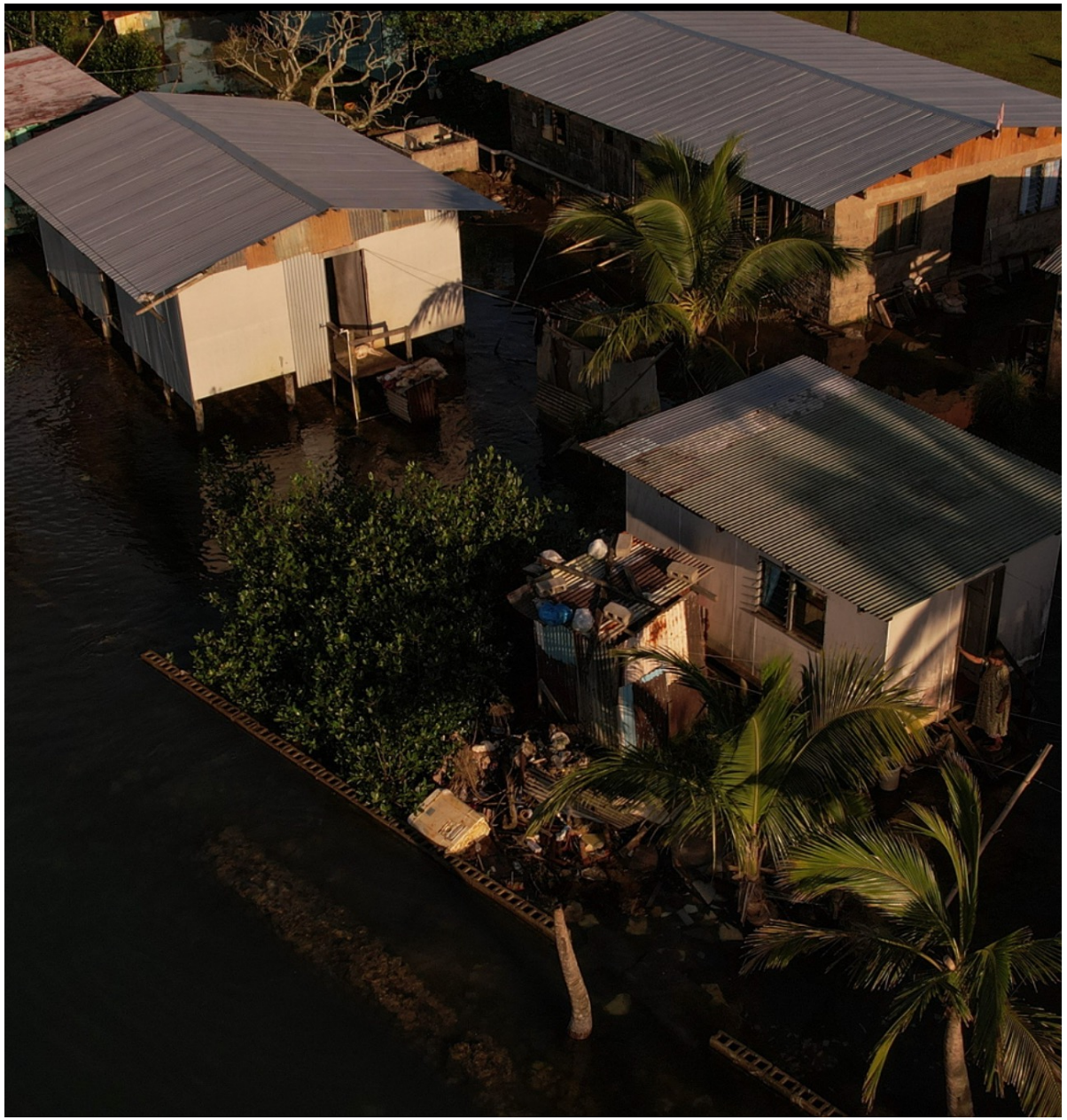




Images From; https://geology.com/world/fiji-satellite-image.shtml
https://www.worldatlas.com/maps/fiji

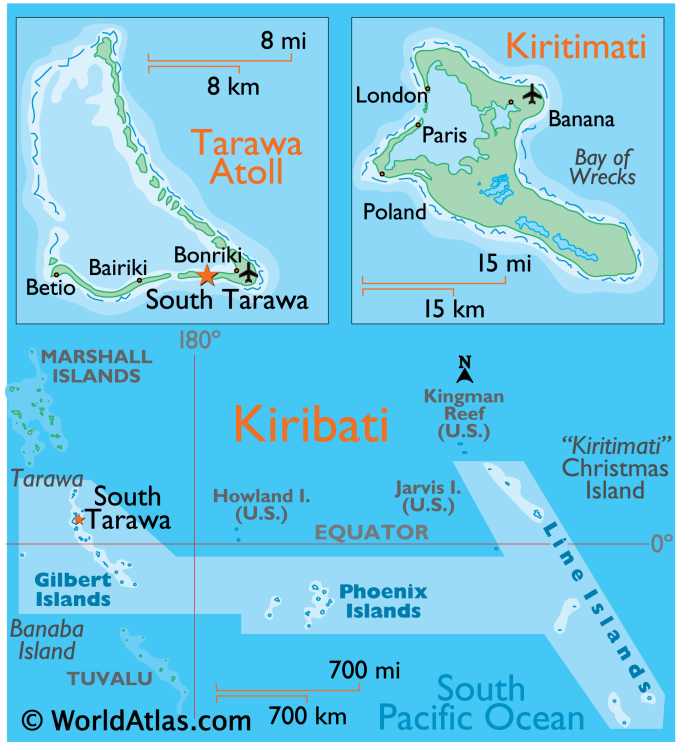


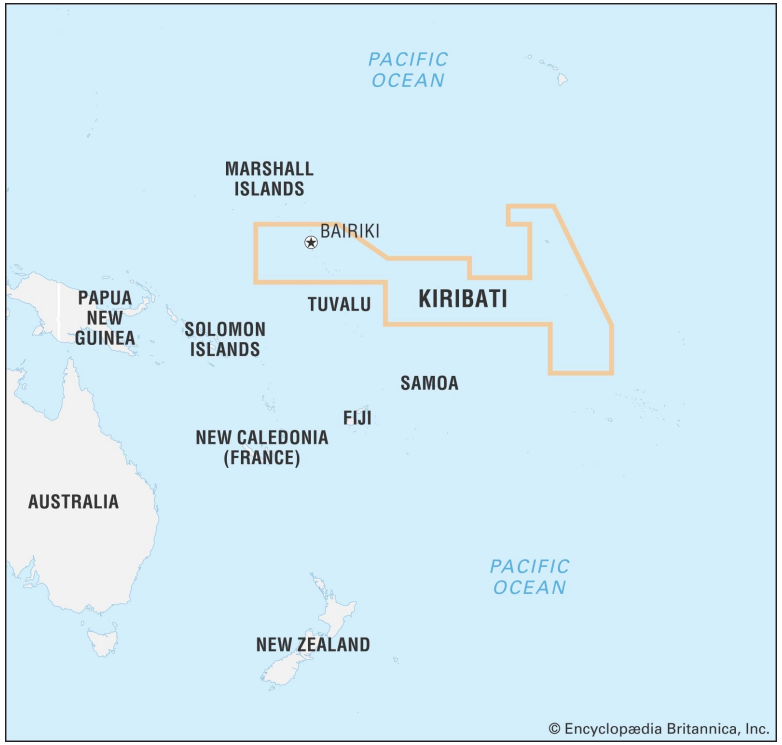
Local resident Roemoni Tubivuna and his grandson Roemoni Tubivuna Jr., 10, prepare a fishing net, as their boat rests against a flooded sea wall which is no longer effective at preventing water intrusion into their community at high tide, in Veivatuloa, Fiji, July 16, 2022. REUTERS/Loren Elliott



https://www.reuters.com/investigates/special-report/climate-change-fiji-sealevels/#:~:text=They%20want%20polluters%20to%20pay%20instead,-By%20Loren%20Elliott&text=Boats%20moor%20next%20to%20living,tide%2C%20flooding%20into%20the%20village.

# Sea Level Rise Impacting Republic of Kiribati


Images From; https://www.britannica.com/place/Kiribati
https://ontheworldmap.com/kiribati/kiribati-location-map.html
https://www.worldatlas.com/maps/kiribati

*Locals regularly have to repair roads damaged by flooding on the islands in the Republic of Kiribati (Credit: Getty Images)*

https://www.bbc.com/future/article/20190813-how-to-save-a-sinking-island-nation

**From The Conversation**

THE CONVERSATION

Weather-related events are estimated to displace 143 million people by 2050 – but rising seas are already threatening tiny tropical nations. Can anything be done to help them?

Kianteata Bwaurerei, 70, has decided not to replant his crops in Abiang after they were inundated. Josh Haner/The New York Times

# Important Takeaways

- If $CO_2$ keep steadily rising and doubles in the  next 100 years, average temperature will increase by 1.3°C - 2.5°C.
- If $CO_2$ were to stabilize at double the preindustrial level temperature will still slowly rise.
- Sea level is projected to rise by 0.4 m over the next century, mostly because of thermal expansion and ice melt.
- Although unlikely, if either the Greenland or West Antarctica ice sheets were to completely melt  there would be a sea-level rise of about 6 m.
- Communities in the Pacific Islands are being disproportionately impacted.