



Sept 23: Major Consequences of Climate Change

Update: quiz 1 moved to next Monday; Student feedback

Foci of the Day

Climate changes occur across both time and space, producing:

- **Direct impacts**
- **Indirect impacts**
- **Positive feedback loops** driven by human behavior and climate interactions

Well known consequences

All of these must be considered from a **global perspective**.

Reading

Levin, K., Boehm, S., & Carter, R. 2022. 6 Big Findings from the IPCC 2022 Report on Climate Impacts. *Adaptation and Vulnerability*.

https://www.wri.org/insights/ipcc-report-2022-climate-impacts-adaptation-vulnerability?utm_source=chatgpt.com



Climate Change: Disrupting the Norms

Temperature-Dependent Sex Determination (TSD)

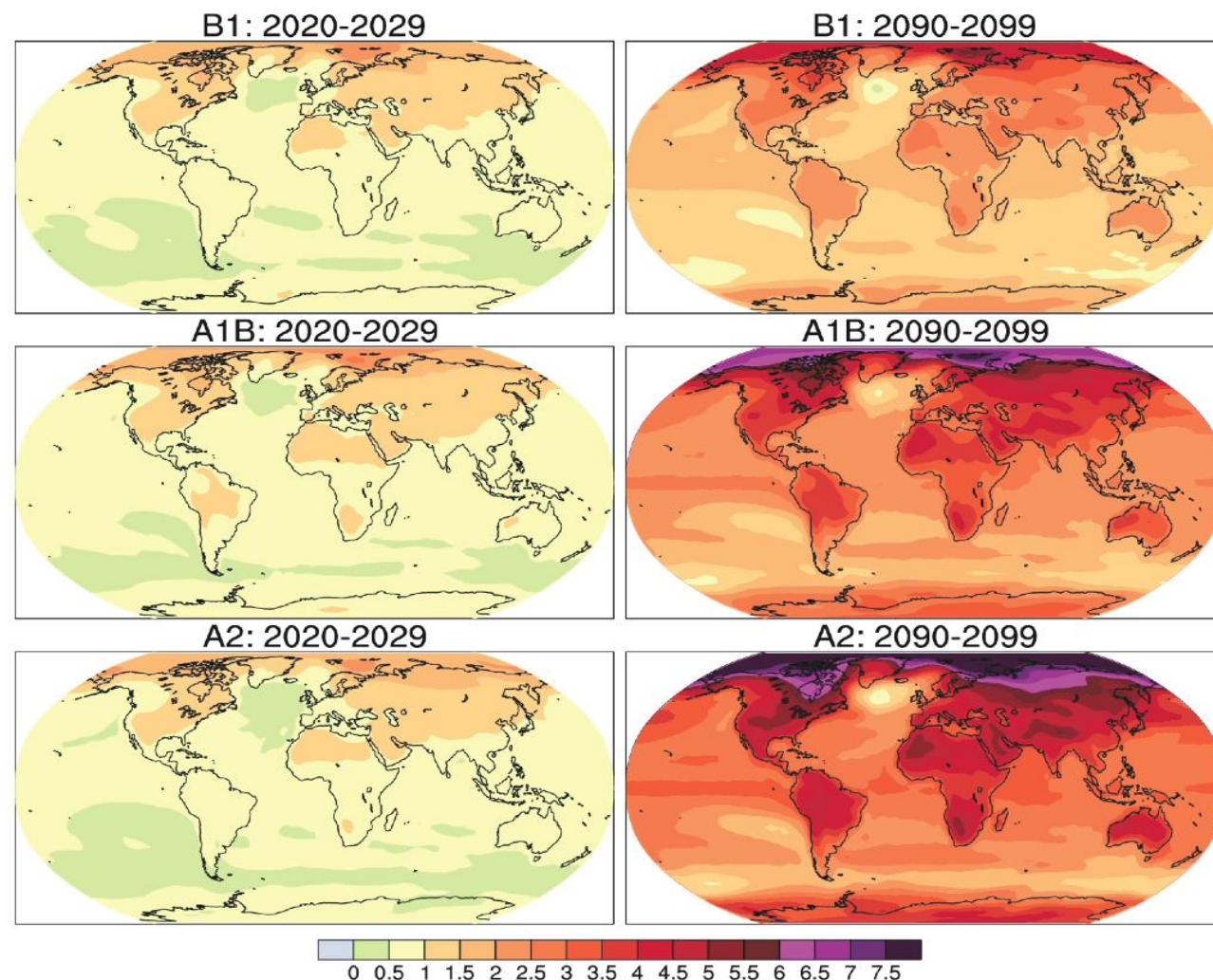


- The sex of most turtles, alligators, and crocodiles is determined after fertilization.
- Most turtles are subject to **TSD**.
- If a turtle's eggs incubate below 27.7°C (81.86°F), the turtle hatchlings will be male.
- If the eggs incubate above 31°C (88.8°F), the hatchlings will be female.
- A slight increase in temperature can lead to a skewed **sex ratio**, thereby elevating the risk of extinction.



Projections of Future Changes in Climate

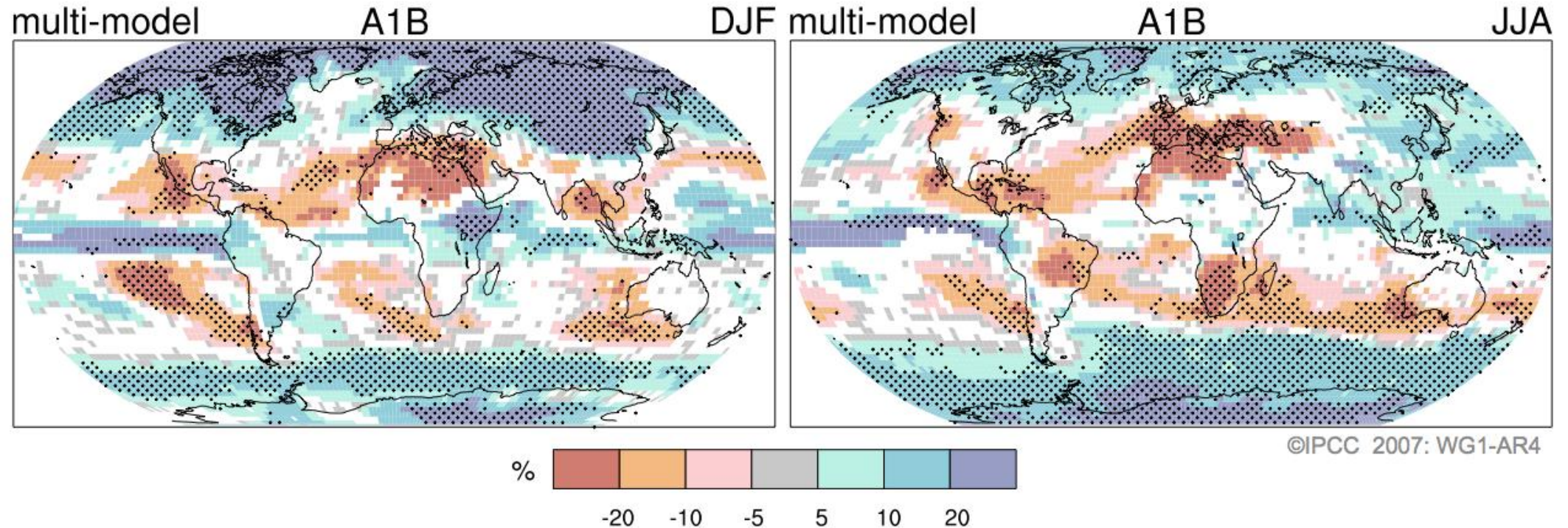
- Projected warming in the 21st century is expected to be most pronounced over land areas and in the high northern latitudes.
- and least over the Southern Ocean and parts of the North Atlantic Ocean





Projections of Future Changes in Climate

Projected Patterns of Precipitation Changes



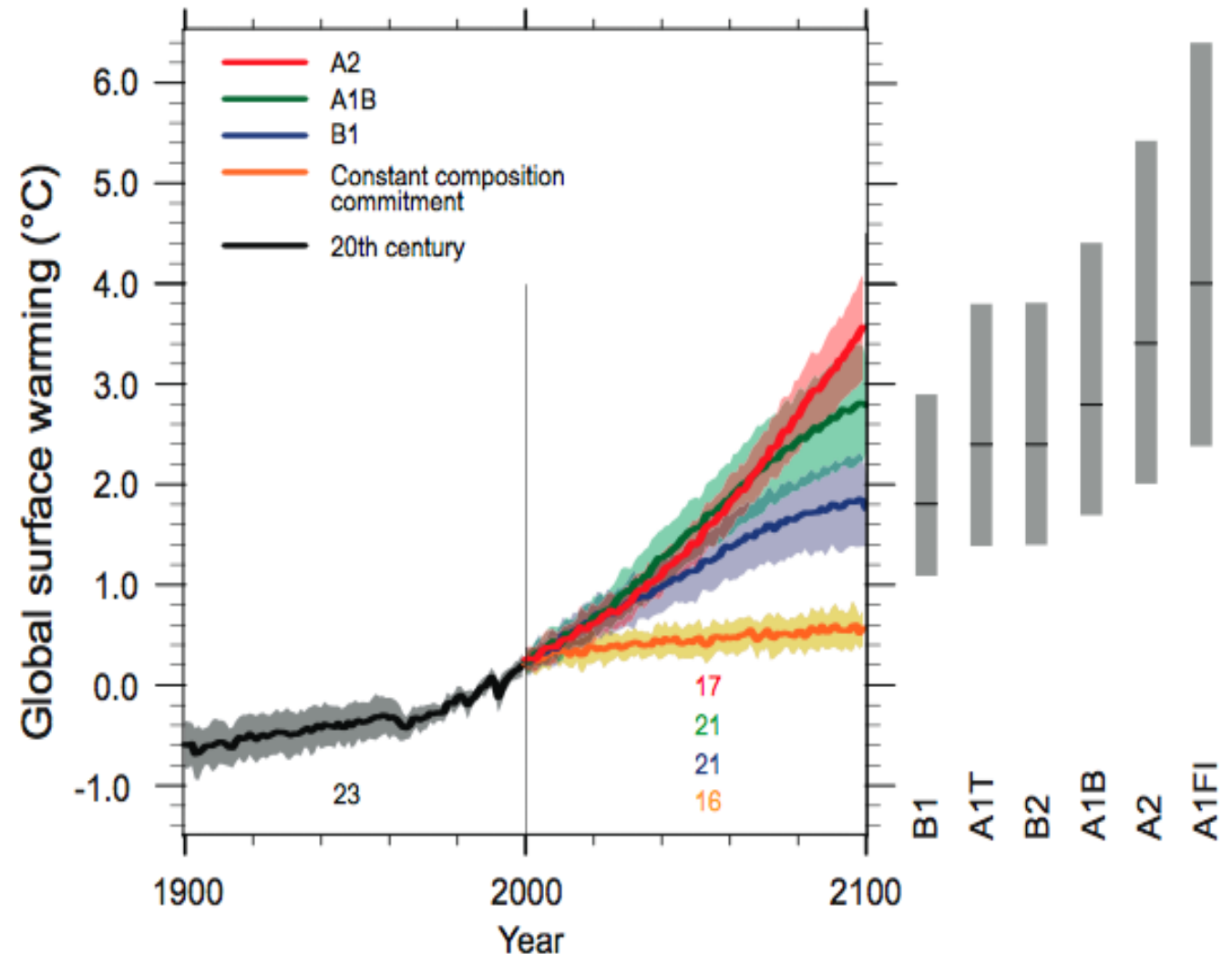
- Precipitation increases *very likely* in high latitudes
- Decreases *likely* in most subtropical land regions



High Uncertainty: Projections of Future Changes in Climate

Best estimate for low scenario (B1) is 1.8°C (*likely* range is 1.1°C to 2.9°C), and for high scenario (A1FI) is 4.0°C (*likely* range is 2.4°C to 6.4°C).

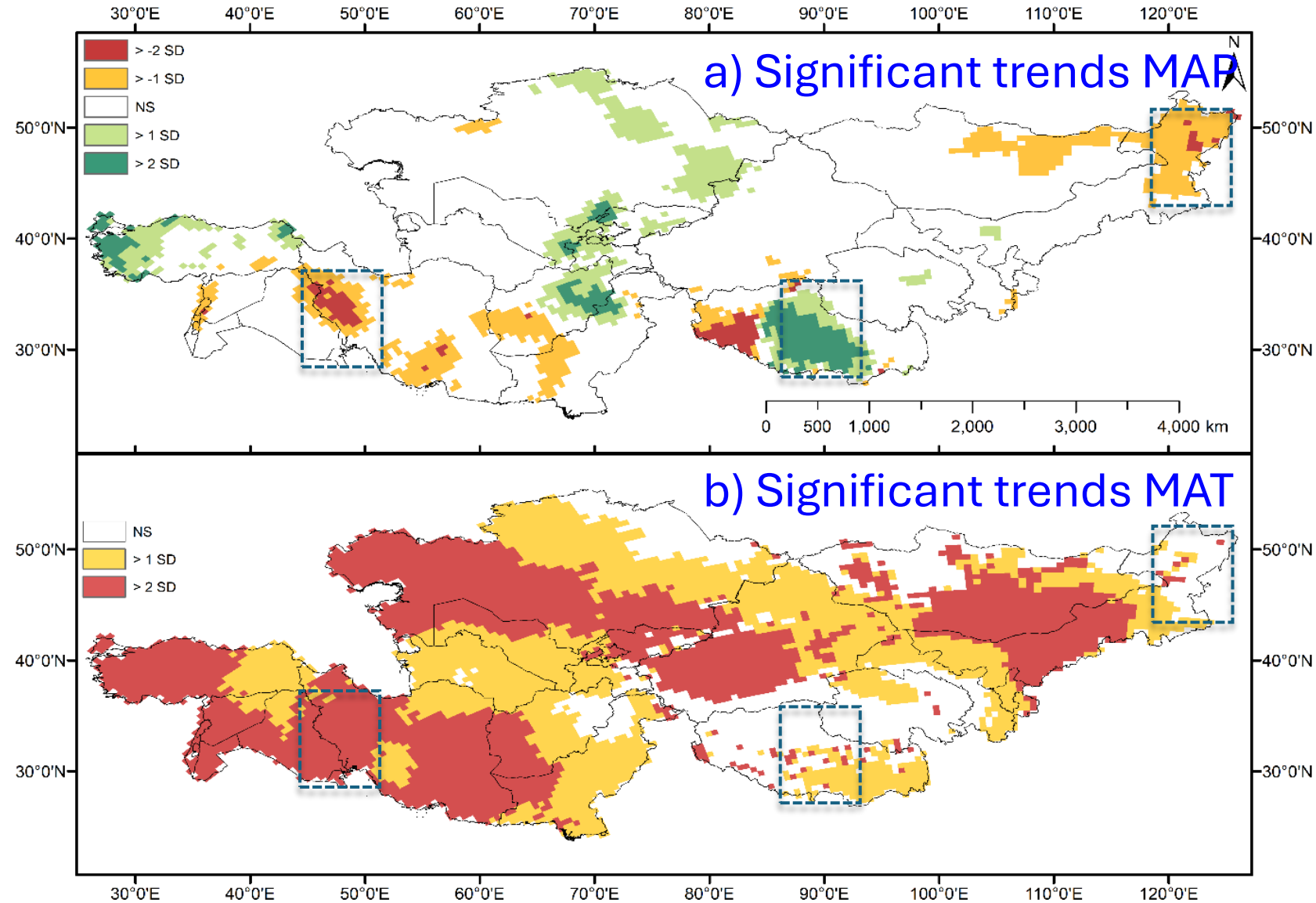
(Credit: Dr. Ying-Ping Wang, CSIRO, Australia)





Climate Change: high spatial variation

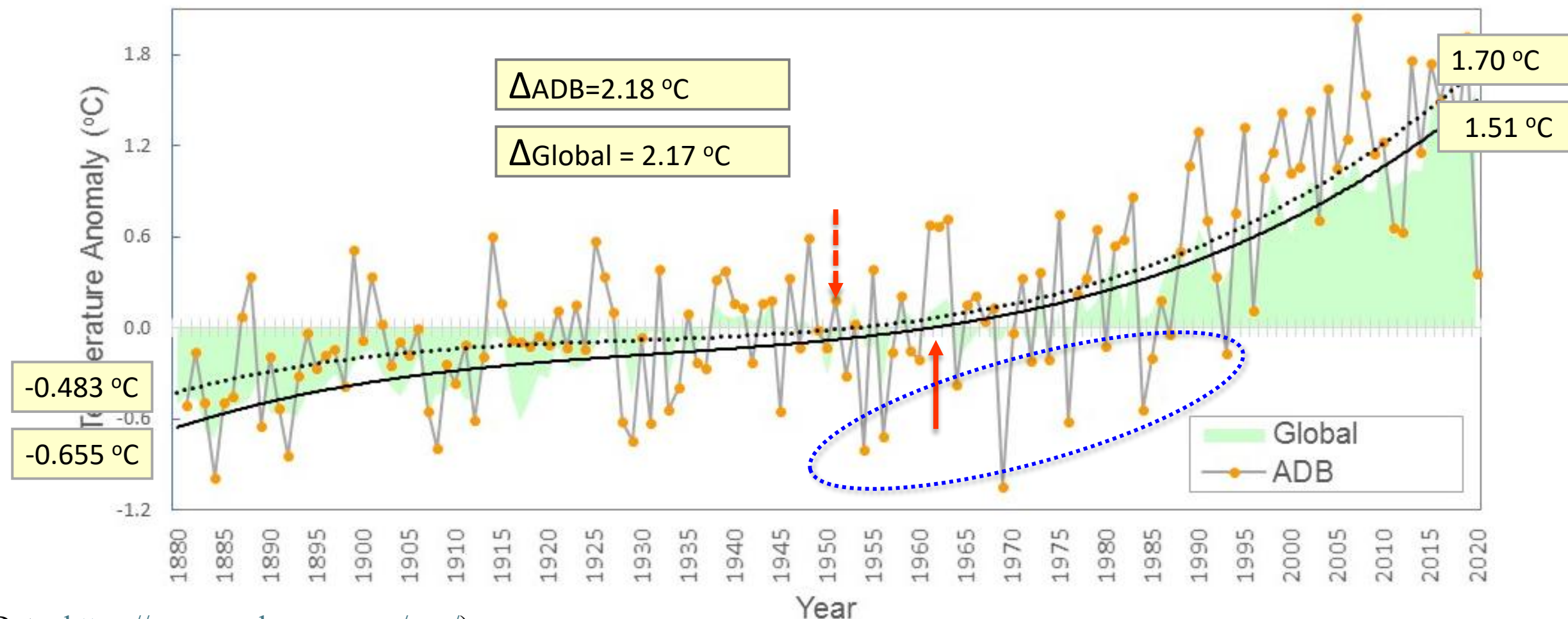
- Long term changes in mean annual precipitation (MAP) and mean annual temperature (MAT) across the Asian Drylands Belt (**ADB**)
- Spatial Variability: not homogeneous and with hotspots



Climate Change: high interannual variation

(Extremes are often related to different physical processes than those that govern long-term means!)

Change in anomalies of land surface air temperature (°C) for global land and ADB region during 1880-2000



(Data: <https://www.ncdc.noaa.gov/cag/>).



Climate Change and Major Impacts

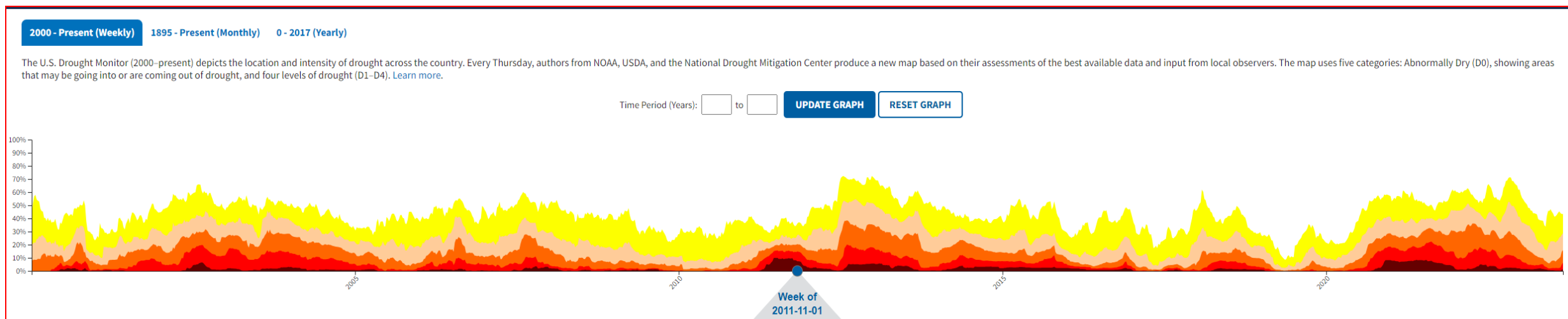
- Sea Level Rise
- Severe Storms
- Changing Currents
- Shrinking Ice Cover (polar bears)
- Bleaching Effect (loss of coral reef)
- Hotter Sands
- Habitat loss for many species
- Urban heat islands (UHI)
- Public health
- More extreme events
- ...

Climate Change: more extreme events

- Heatwaves
- Drought
- Frosts in springs/falls
- Extreme precipitation
- Dzuds (extreme cold winter)
- ...



<https://www.nationalgeographic.com/photography/article/extreme-winter-mongolia-dzud-environment-science>



[https://www.drought.gov/historical-](https://www.drought.gov/historical-information)

information. State: 22, County: ID, USDM: 2011-11-01



Climate Change: Full of Surprises

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**Festivalgoers were told to shelter in place
in the Black Rock Desert and conserve
food, water and fuel**



Why is global sea level rising?

Melting land ice: Changes in the volume of water and ice on land (i.e., glaciers and ice sheets) can increase or decrease the volume of water in the ocean

Thermal expansion: As water warms, it expands slightly—an effect that is cumulative over the entire depth of the oceans

How fast is sea level rising?

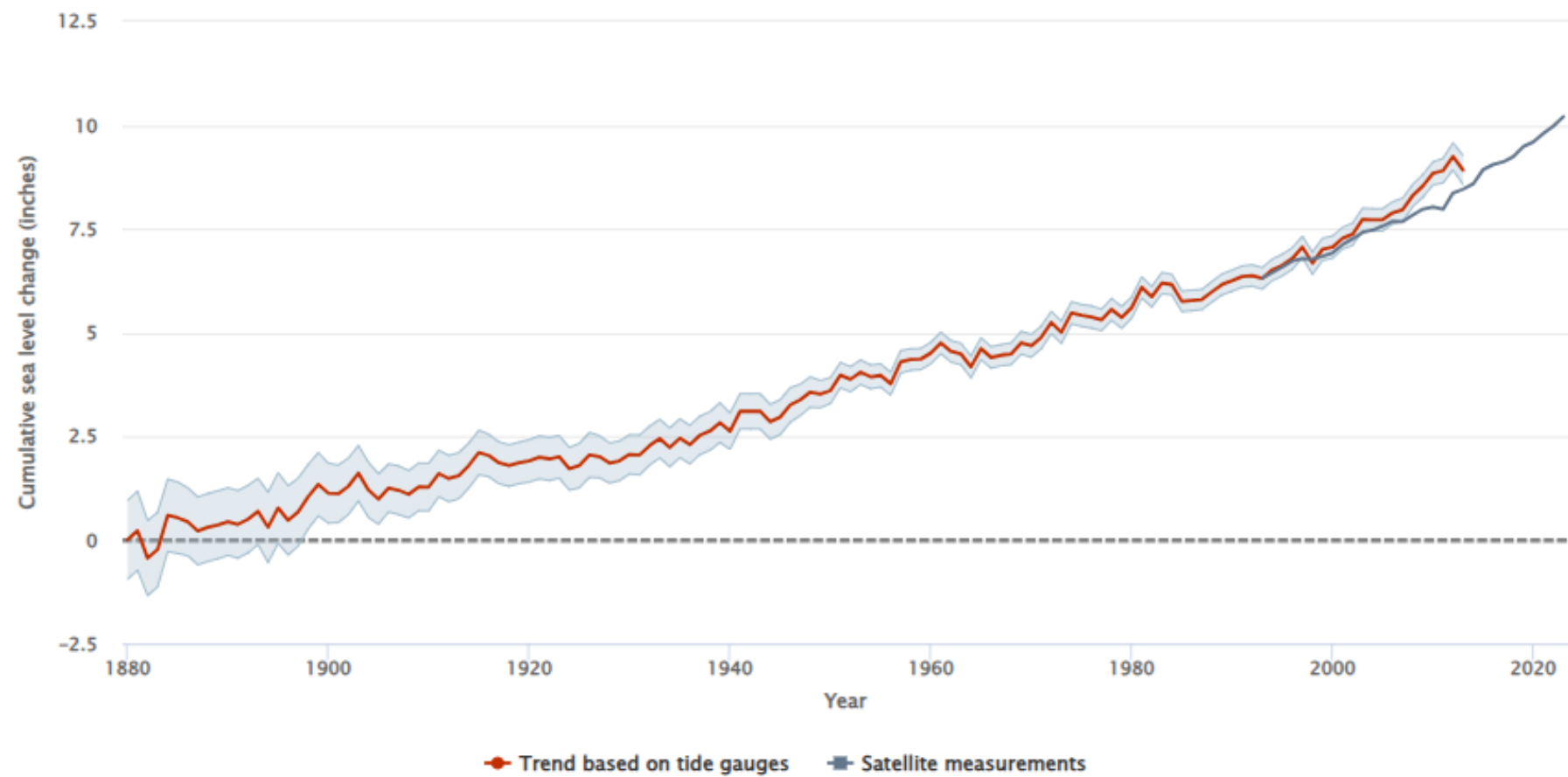
Climate Change Indicators: Sea Level (EPA)

(<https://www.epa.gov/climate-indicators/climate-change-indicators-sea-level#:~:text=Relative%20sea%20level%20data%20are%20available%20from,to%20detailed%20data%20for%20each%20tide%20gauge>)

After a period of ~2,000 years of little change, global average sea level rose throughout the 20th century, and the rate of change has accelerated in recent years. When averaged over all of the world's oceans, absolute sea level rose **0.06"/year** during 1880-2013. Since 1993, average sea level rose at a rate of **0.12"/year**—roughly twice as fast as the long-term trend.

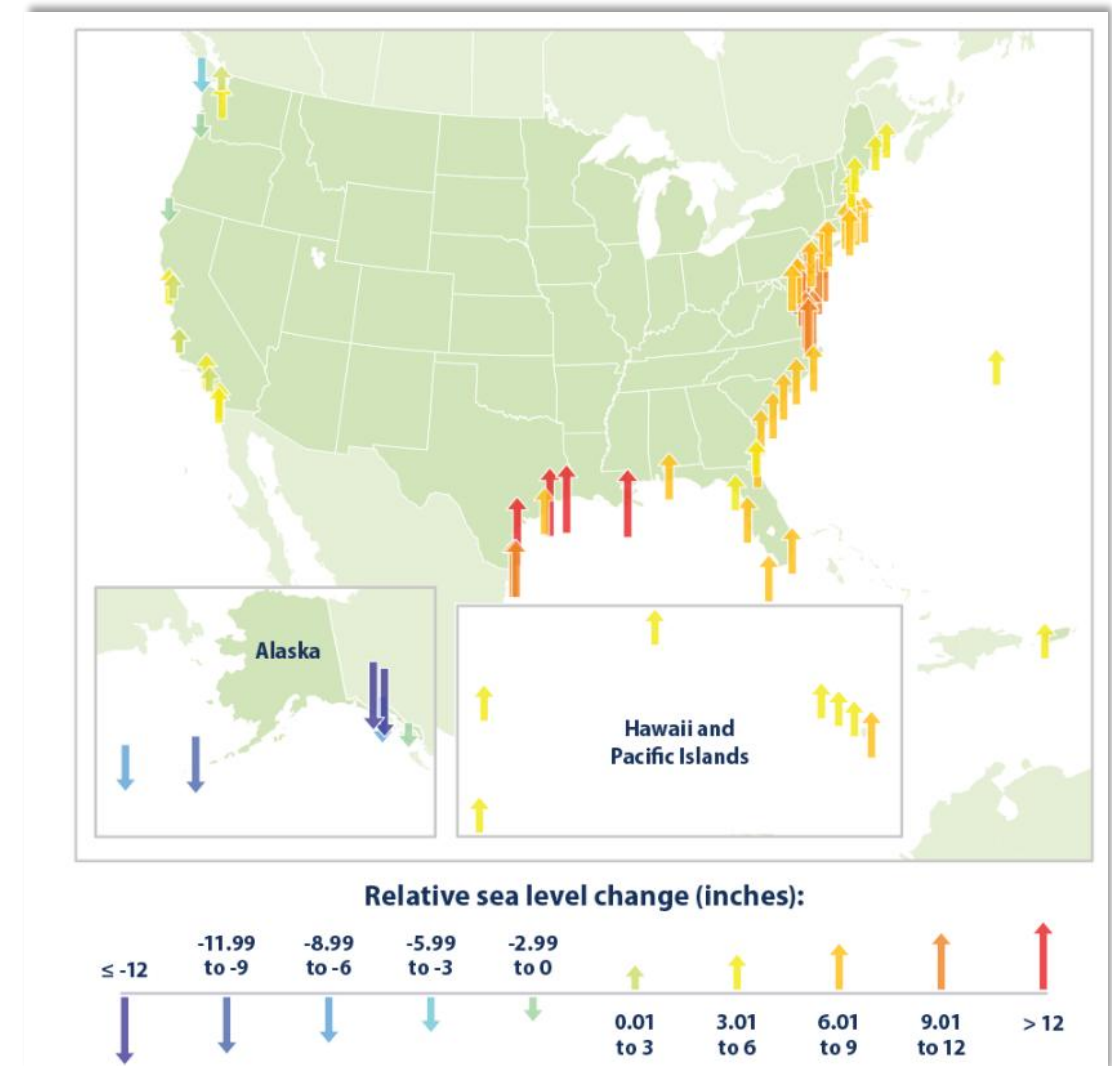


Figure 1. Global Average Absolute Sea Level Change, 1880–2023



Cumulative changes in relative sea level from 1960 to 2023 at tide gauge stations along U.S. coasts. Relative sea level reflects changes in sea level as well as land elevation.

While absolute sea level has increased steadily overall, particularly in recent decades, regional trends vary, and absolute sea level has decreased in some places. Relative sea level also has not risen uniformly because of regional and local changes in land movement and long-term changes in coastal circulation patterns.





What are the consequences?

Sea level rise carries many kinds of risks for people, ecosystems and infrastructure:

- **Increased flooding & coastal inundation:** Higher sea levels mean that high tides can reach further inland and that storm surges become more damaging.
- **Erosion of beaches and coastlines:** As sea levels rise, waves reach further and erode land more quickly.
- **Saltwater intrusion:** Seawater can move into freshwater systems (aquifers, estuaries), threatening drinking water supplies, agriculture, and ecosystems.
- **Impacts on ecosystems:** Wetlands, mangroves and other coastal habitats may be drowned or reduced, affecting species and reducing natural protection against storms.
- **Infrastructure and economic impacts:** Roads, power plants, sewage systems, buildings near the coast are exposed to greater risk and higher maintenance/adaptation costs.



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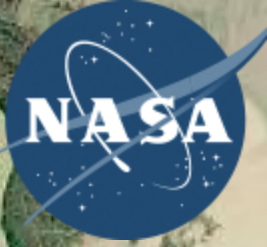


Nearly 200,000 homes in England could be lost to rising sea in next 30 years, study warns
(<https://www.independent.co.uk/climate-change/news/sea-level-rise-homes-coastal-erosion-b2101359.html>)





Reshaping Coastal Louisiana



Visible Earth

(<https://visibleearth.nasa.gov/collection/1684/sea-level-rise>)





In many locations along the U.S. coastline, the rate of local sea level rise is greater than the global average due to land processes like erosion, oil and groundwater pumping, and subsidence.





Children play on a fortified beach in Temwaiku, a village on the Tarawa atoll, the capital of the Pacific island nation of Kiribati.

(<https://www.nrdc.org/stories/these-photographs-show-how-rising-sea-connects-us-all>)





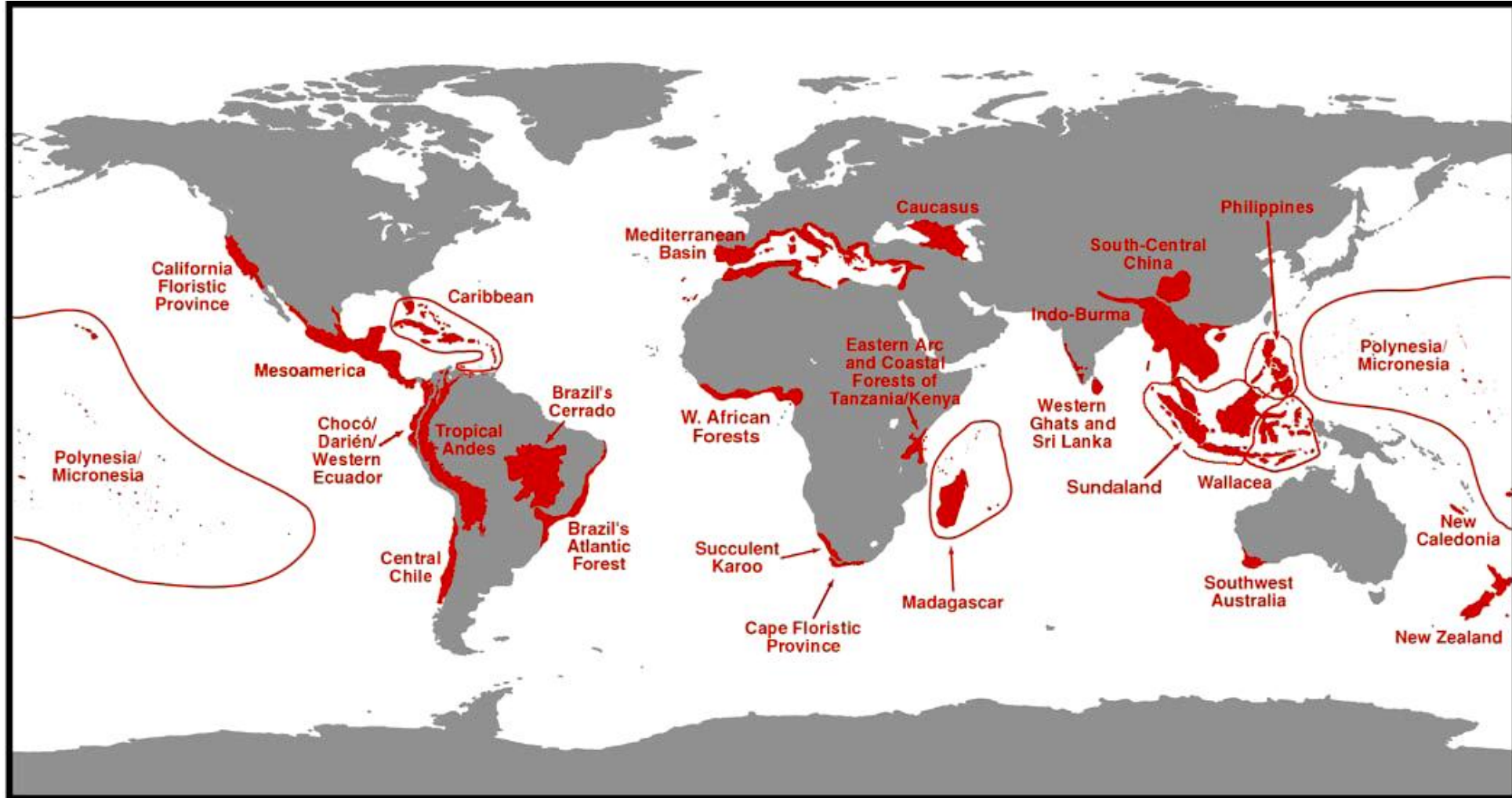
Rising Sea Levels Putting New York City at Risk (WSJ)

<https://www.youtube.com/watch?v=-xLokKVdk7I>





Indirect Impact: The 25 hotspots, most in coastal areas that will be hit first by the rising seas





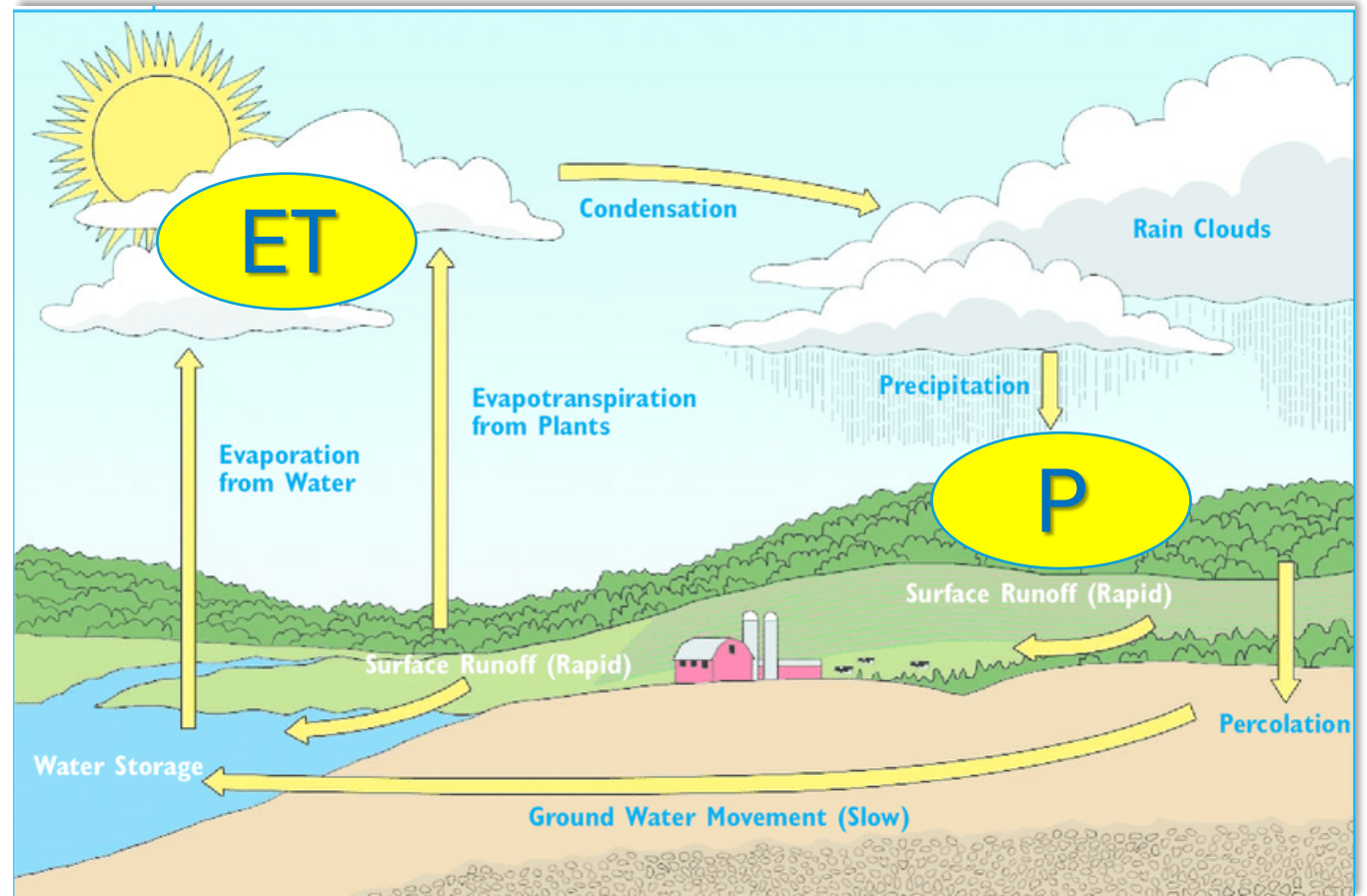
A Story About the Giant Sequoia
(*Sequoiadendron giganteum*)



A Thirsty Globe!

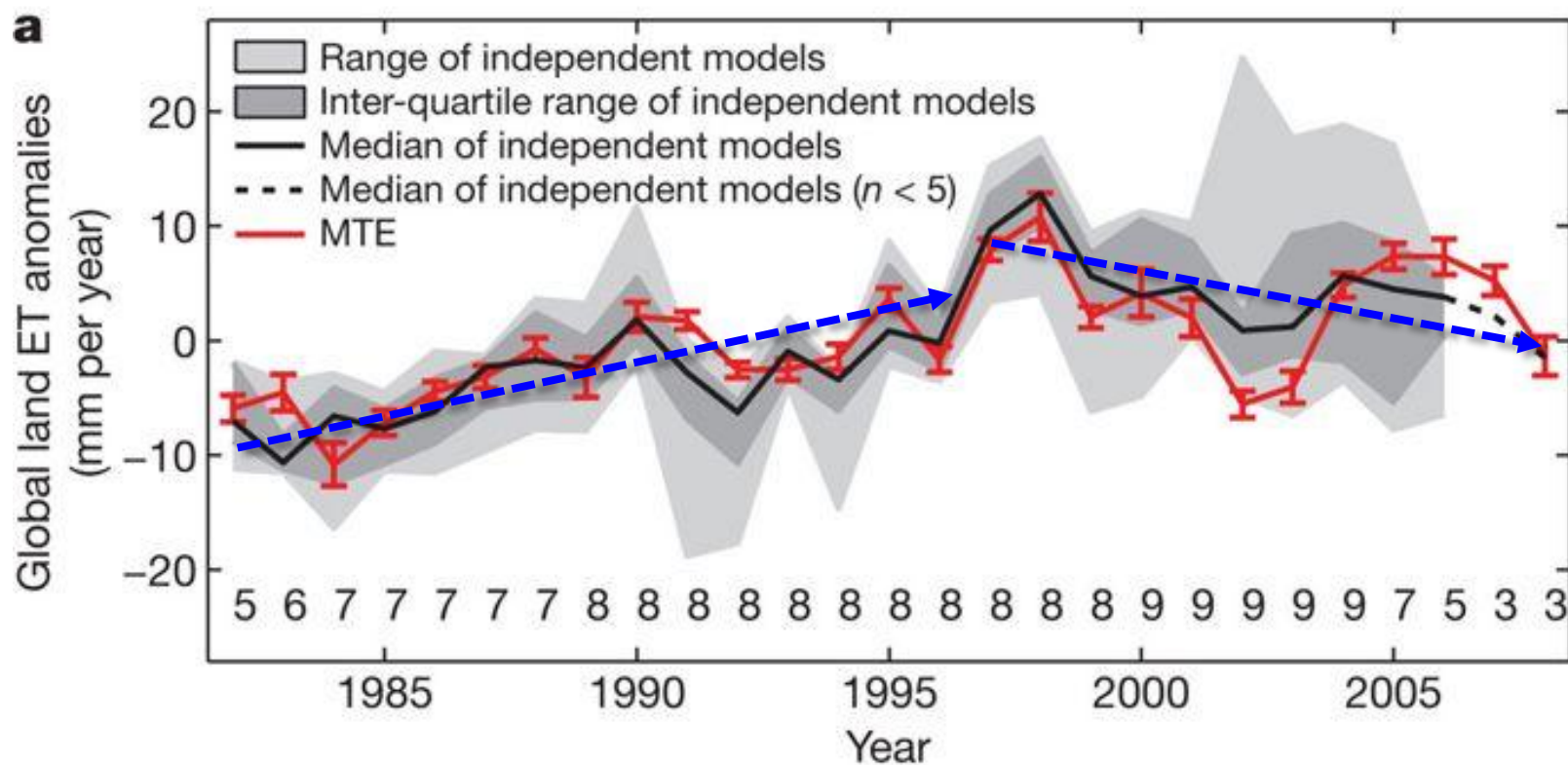
- Evapotranspiration (**ET**): the total amount of water transferred from the land surface to the atmosphere through evaporation and plant transpiration.

- Although total global precipitation (**P**) remains relatively constant over time, changes in **ET** influence the availability of water in soils, rivers, and groundwater systems.



A Thirsty Globe!

- ET has been increasing with warming climate until ~1998, but decreasing since then;
- We may have more freshwater;





A Thirsty Globe!

Unfortunately

- This change was driven primarily by **moisture limitation** in the Southern Hemisphere, particularly **Africa** and **Australia**.
- In these regions, soil moisture decreased from 1998 to 2008.
- Hence, increasing soil-moisture limitations on ET, largely explain the recent decline of the global ET.

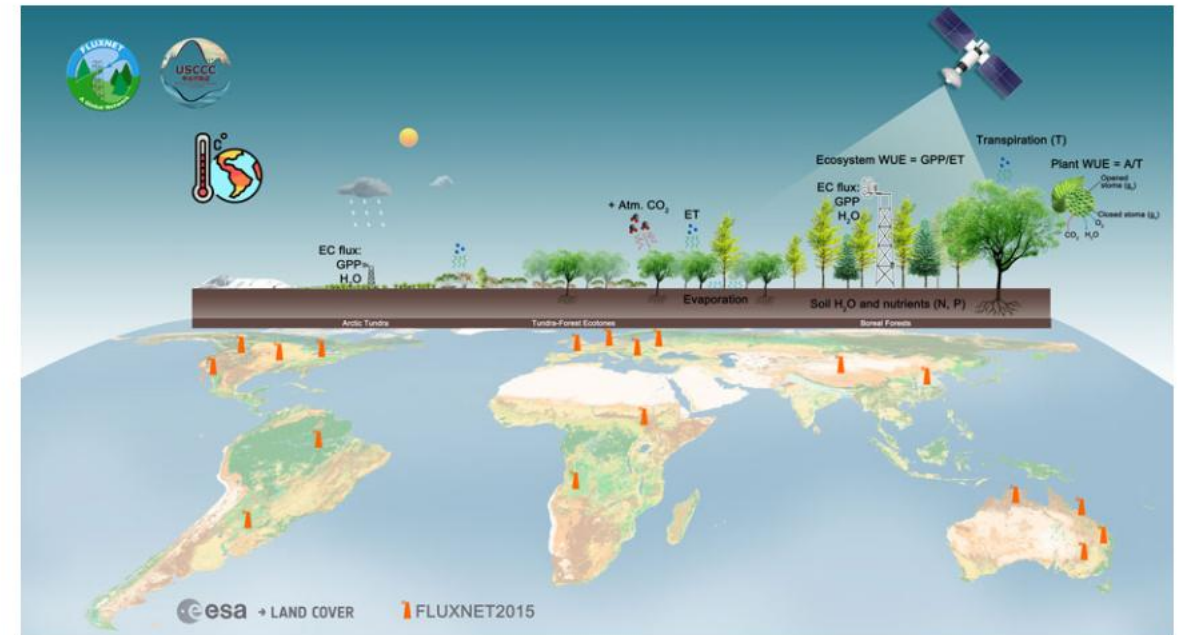
Climate Change: Full of Surprises

- Ecosystem water use efficiency ($WUE_{eco} = GPP:ET$), is widely expected to increase because of the rising atmospheric CO_2 concentration,
- Global WUE_{eco} has not risen since 2001 because of the asymmetric effects of an increased vapor pressure deficit **due to the warming**, which depressed photosynthesis (GPP) and enhanced ET.

MSU scientists find plants' ability to fight climate change is weakening

August 16, 2023 - Diane Huhn

New findings shed light on global water use efficiency in terrestrial ecosystems



Data knowledge predictions about global water use efficiency in a changing climate. (Image courtesy of Jiquan Chen/Landscape Ecology & Ecosystem Science Lab)

It's often said that you should never put all your eggs in one basket. New research indicating that plants' ability to absorb carbon dioxide (CO_2) may have stalled, just published in the journal *Science* by climate experts at Michigan State University, suggests that perhaps we shouldn't put all our climate mitigation hopes in too many plant-based strategies either, at least for the time being.

Li, F., Xiao, J., Chen, J., Ballantyne, A., Jin, K., Li, B., ... & John, R. (2023). Global water use efficiency saturation due to increased vapor pressure deficit. *Science*, 381(6658), 672-677.





Lake Disappearance!

- Hundreds lakes across the globes disappear each year, especially in dryland regions.
- Over the last 60 years, the lake's size has decreased by 90% as a result of overuse of the water, extended drought and the impacts of climate change.
- The surface area of the lake has plummeted from 26,000 km² in 1963 to <1,500 km² today (2018) -- **shrank by 20 times.**

List of drying lakes

From Wikipedia, the free encyclopedia

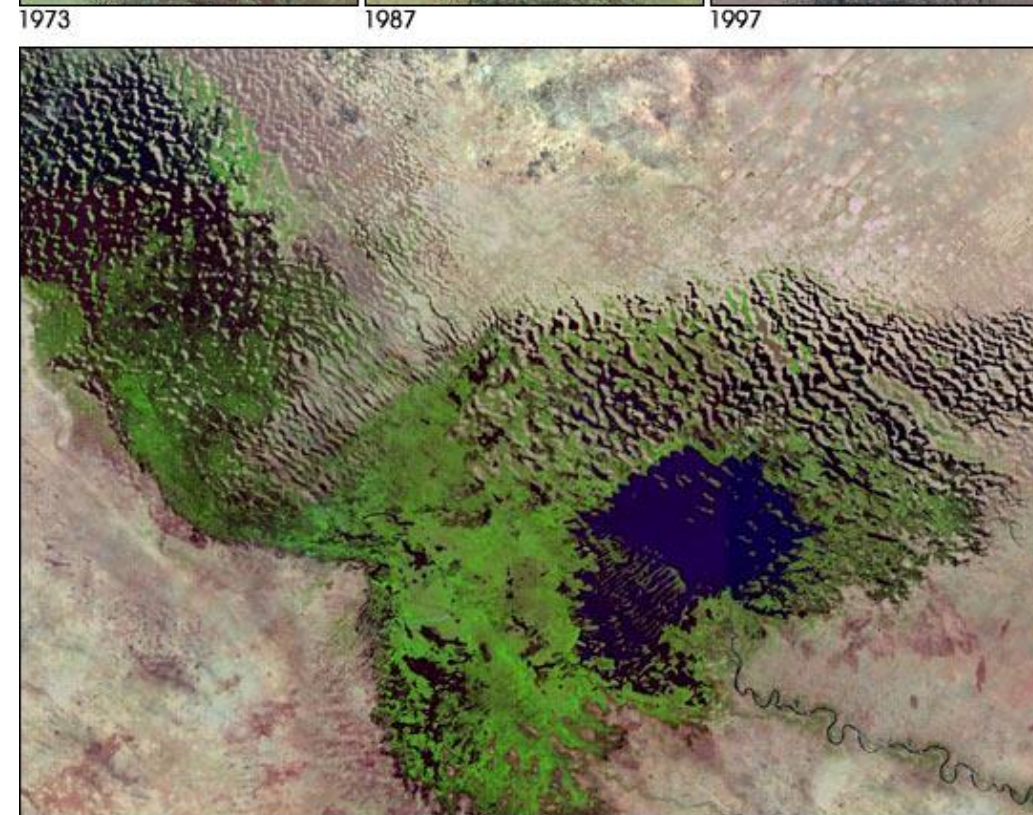
A number of lakes throughout the world are drying or completely dry due to [irrigation](#) or urban use diverting inflow.^{[1][2]}

This list is incomplete; you can help by expanding it.

- | | | |
|---|--|---|
| • Dead Sea in Israel, Jordan, and Palestine ^[3] | • Owens Lake in California, U.S. ^[10] | • White Bear Lake in Minnesota, U.S. ^[1] |
| • Hamun Lake on the Irano-Afghan border ^[4] | • Walker Lake in Nevada, U.S. ^[11] | • Lake Meredith in Texas, U.S. ^[15] |
| • Salton Sea in California, U.S. ^[5] | • Mono Lake in California, U.S. ^[12] | • Lake Albert in South Australia ^[16] |
| • Lake Chad in Cameroon, Chad, Niger and Nigeria ^[6] | • Fucine Lake in Italy (fully drained during the 19th century) | • Lake Hindmarsh in Australia ^[17] |
| • Aral Sea in Kazakhstan and Uzbekistan ^[7] | • Poyang Lake in Jiangxi, China ^[13] | • Lake Poopó in Bolivia ^[18] |
| • Tulare Lake in California, U.S. ^[8] | • Qinghai Lake in China | • Lake Copais, in Boeotia, Greece |
| • Lake Urmia in Iran ^[9] | | • Lake George, in New South Wales, A |



Lake Chad, once one of the African continent's largest bodies of fresh water, has dramatically decreased in size due to climate change and human demand for water.



2001

<https://earthobservatory.nasa.gov/images/1240/africas-disappearing-lake-chad>



Aral Sea: Once the fourth largest lake in the world



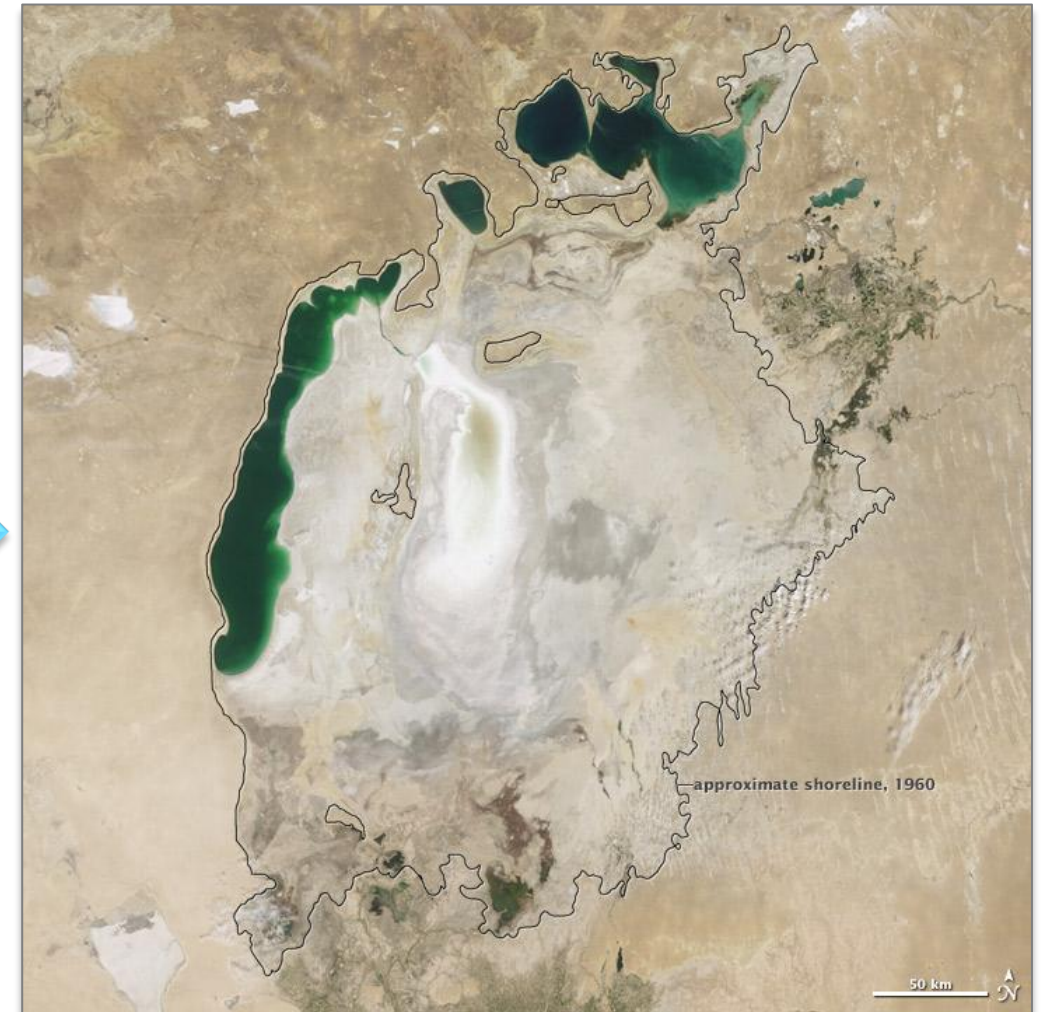


Aral Sea

1963



2019





What had happened?

- **Virgin Lands Campaign:** A Soviet initiative launched in the mid-1950s to cultivate previously uncultivated lands in Central Asia and other regions.
- Most regional renewable water resources originate in the mountains, where the major rivers of the region begin.
- Extensive irrigation systems have been developed to enhance soil fertility.

- High ET loss
- Less inflows from rivers
- More water withdraw



<https://www.youtube.com/watch?v=DsUYt9tIsos>



Take-Home-Messages

- 1) Warming has increased evapotranspiration (ET), but this trend has been constrained by reduced soil moisture since 1998.
- 2) Ecosystem water use efficiency (WUE) exhibited a noticeable shift after 2001.
- 3) The Aral Sea experienced both shrinkage and expansion due to land-use changes.

A Thirsty Globe!