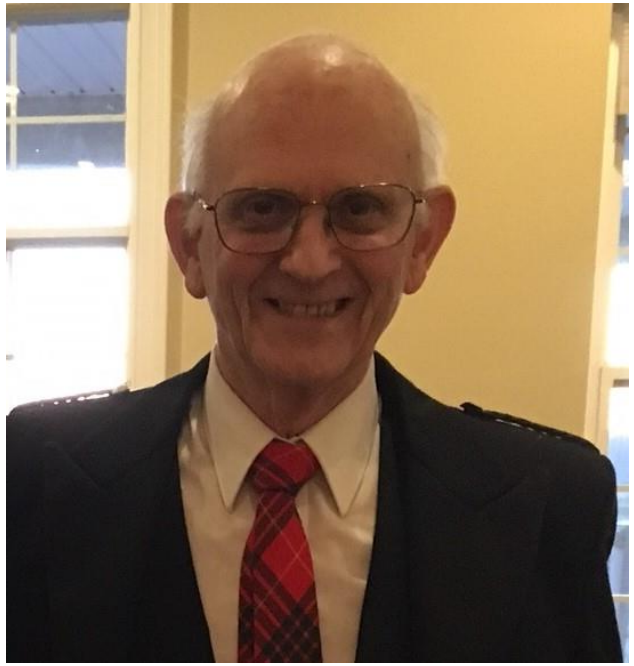
Climate Change Affecting Agriculture and Fisheries



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United Nations Definitions of Climate Change Terms

IPCC and UNFCCC

- The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the United Nations founded in 1988.
- The IPCC produces reports that contribute to the work of the United Nations Framework Convention on Climate Change (UNFCCC), the main international treaty on climate change.
- The objective of the UNFCCC is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (human-induced) interference with the climate system"

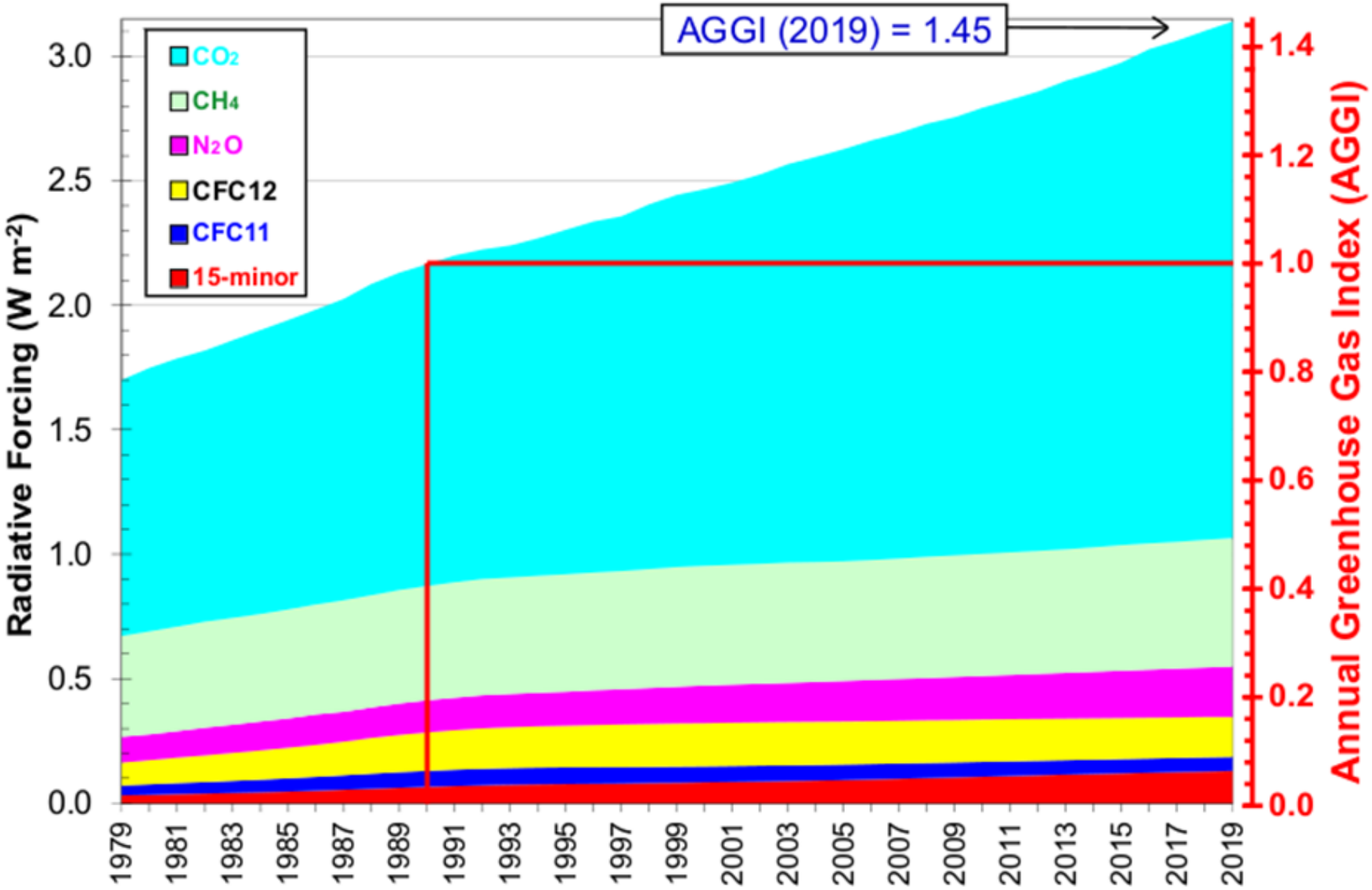
Representative Concentration Pathway (RCP)

- A Representative Concentration Pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC.
- Four pathways were used for climate modeling and research for the IPCC fifth Assessment Report (AR5) in 2014.
- The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come.
- The RCPs – originally RCP2.6, RCP4.5, RCP6, and RCP8.5 – are labelled after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6, and 8.5 Watts per square meter (W/m^2), respectively).

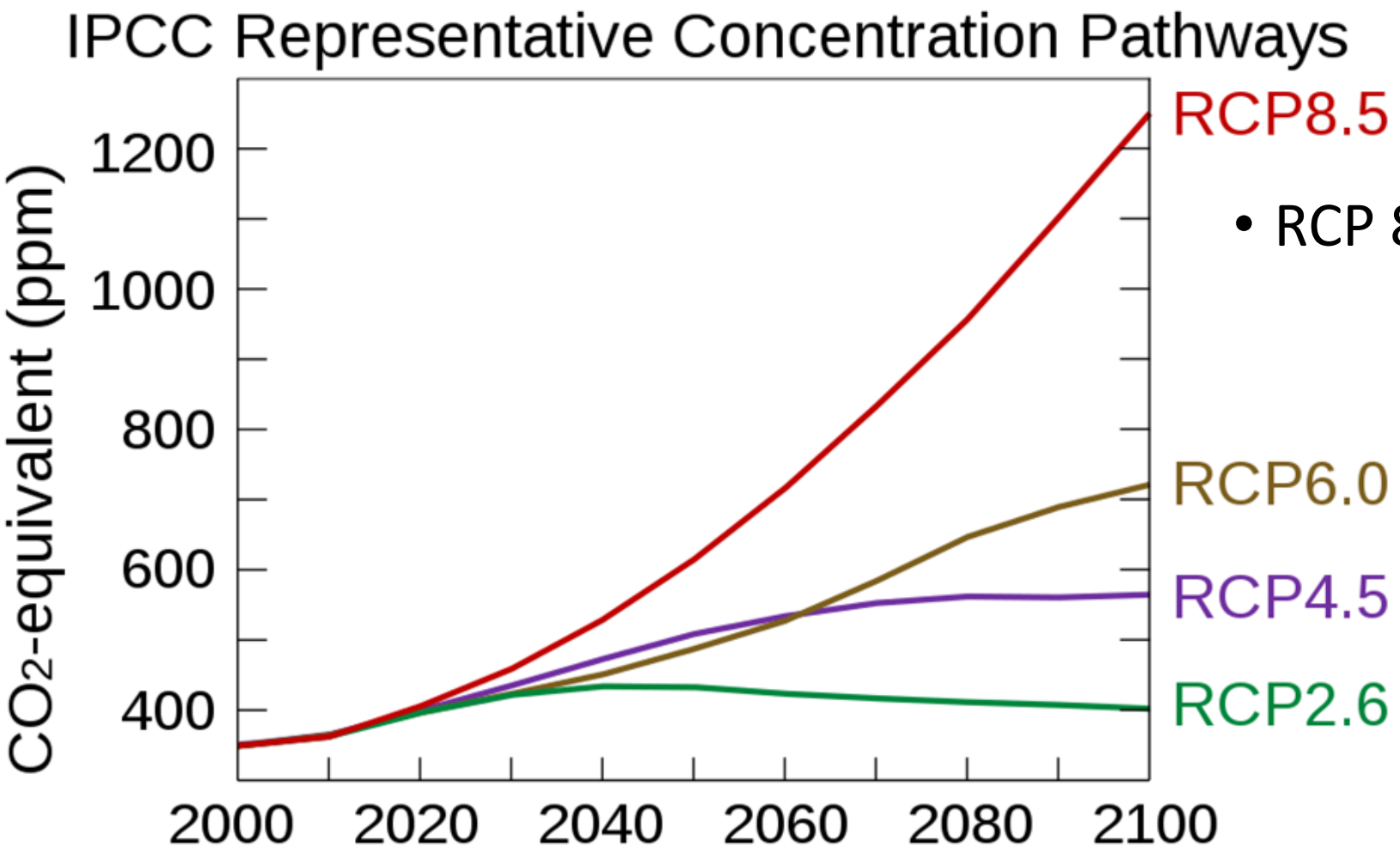
Radiative Forcing

- "Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism.
- Radiative forcing values are for changes relative to preindustrial conditions defined at 1750 and are expressed in Watts per square meter (W/m^2).

Agents Contributing to Radiative Forcing



Four RCP Scenarios

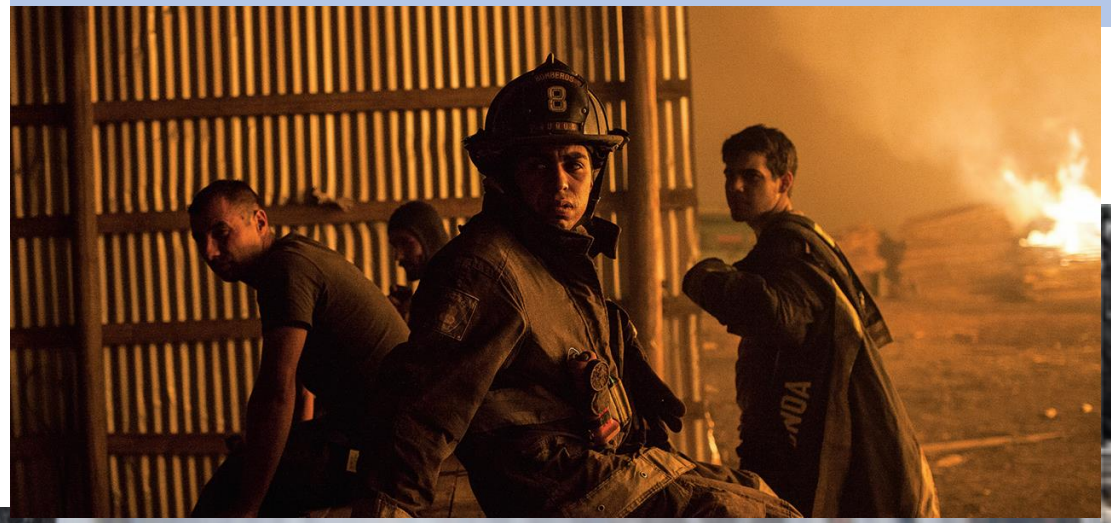


- RCP 8.5 = business as usual

Climate Change Effects on the Land and Agriculture

Azuza: the Ranch 2 Fire burned more than 4,200 acres, part of the worst wildfire season in California history

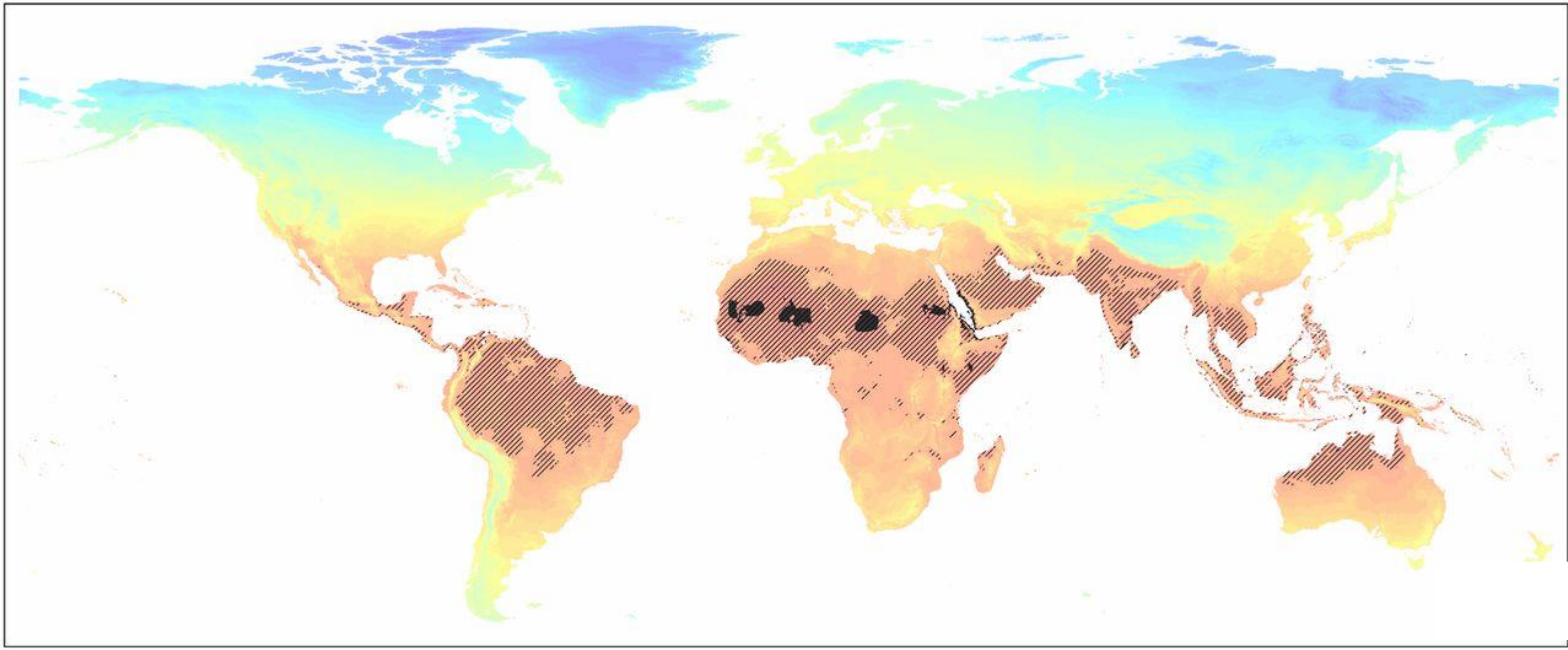
Wildfires in Chile and Australia

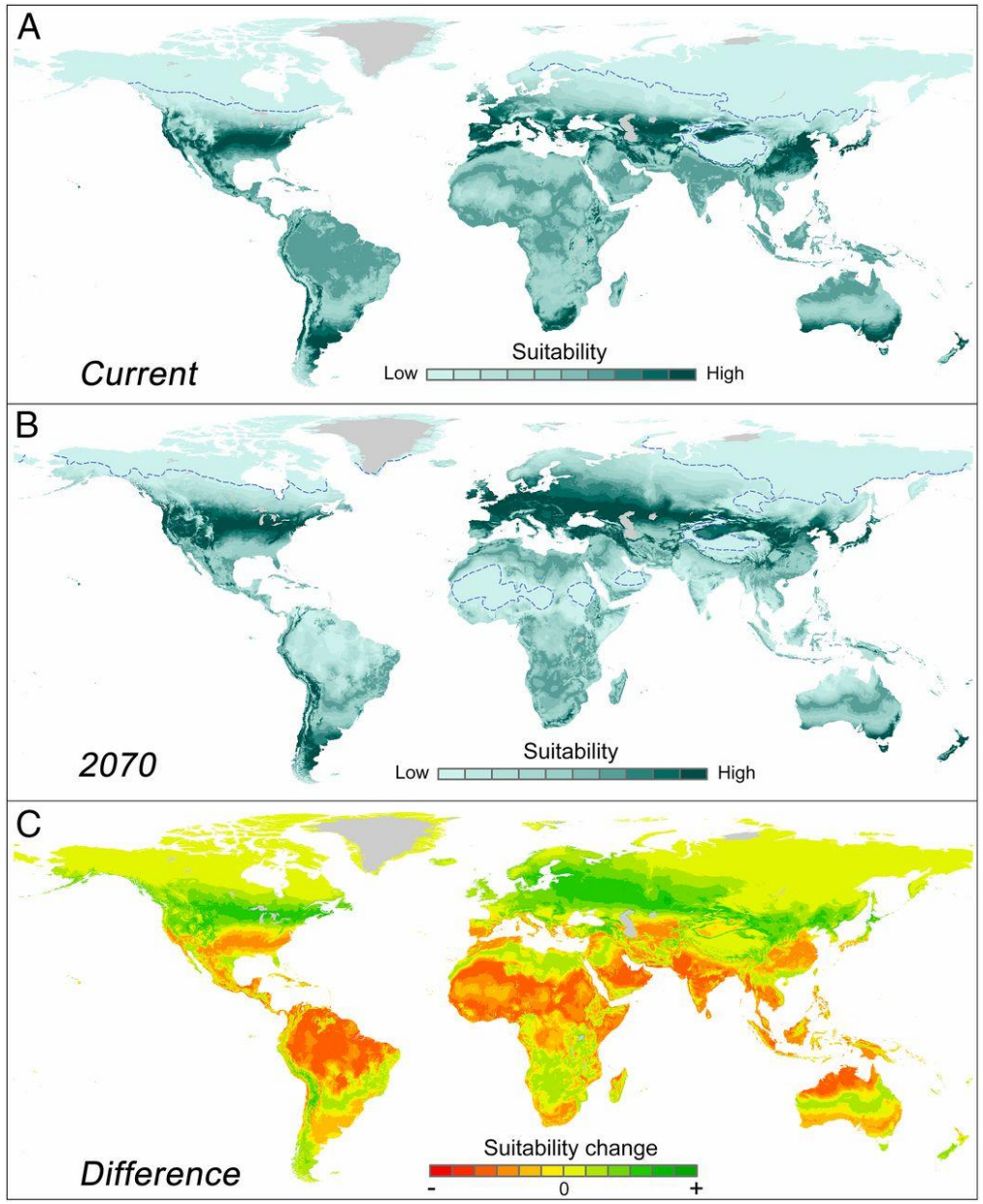


Current Climate Challenges in the USA Exacerbated by Global Warming

- Droughts regularly threaten food crops across the West
- Destructive floods inundate towns and fields from the Dakotas to Maryland, collapsing dams in Michigan and raising the shorelines of the Great Lakes.
- Rising seas and increasingly violent hurricanes are making thousands of miles of American shoreline becoming increasingly uninhabitable
- Hurricane Laura pounded the Louisiana coast with 150-mile-an-hour winds, killing at least 25 people; it was the 12th named storm to form by that point in 2020, another record. More hurricanes to come
- Phoenix, meanwhile, endured 53 days of 110-degree heat — 20 more days than the previous record.
- Multiple devastating wildfires in California and other western states

Expansion of extremely hot regions in a business-as-usual climate scenario (RCP8.5). Now MATs >29 °C are restricted to the small dark areas in the Sahara region. In 2070, such conditions are projected to occur throughout the shaded area. Unless they move, this would be home to 3.5 billion people. Background colors represent the current MATs (Xu et al., 2020).





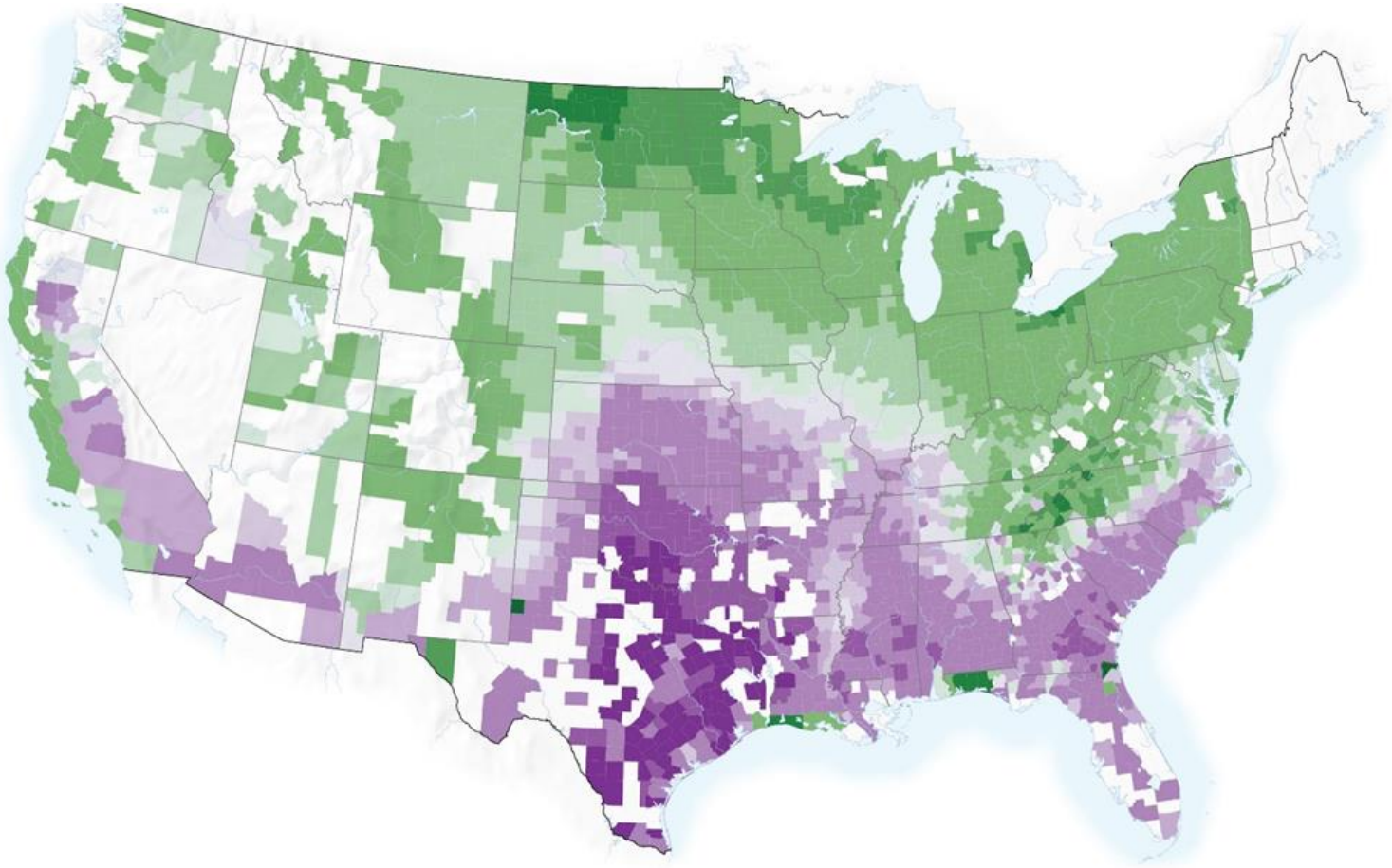
Projected Geographical Shift of the Human Temperature Niche (Xu et al., 2020)

- A: Current situation
- B: RCP 8.5 projected 2070 climate
- C: Difference between the maps, visualizing potential source (orange) and sink (green) areas for the coming decades if humans were to be relocated in a way that would maintain this historically stable distribution with respect to temperature.

Anthropogenic Climate Change Has Driven Over 5 Million Km^2 of Drylands Towards Desertification (Burrell et al., 2020)

- Drylands cover 41% of the earth's land surface and include 45% of the world's agricultural land.
- These regions are among the most vulnerable ecosystems to anthropogenic climate and land use change and are under threat of desertification.
- Between 1982 and 2015, anthropogenic climate change has degraded 12.6% of drylands, contributing to desertification and affecting 213 million people, 93% of who live in developing economies.

Farm Crop Yields: 2040-2060



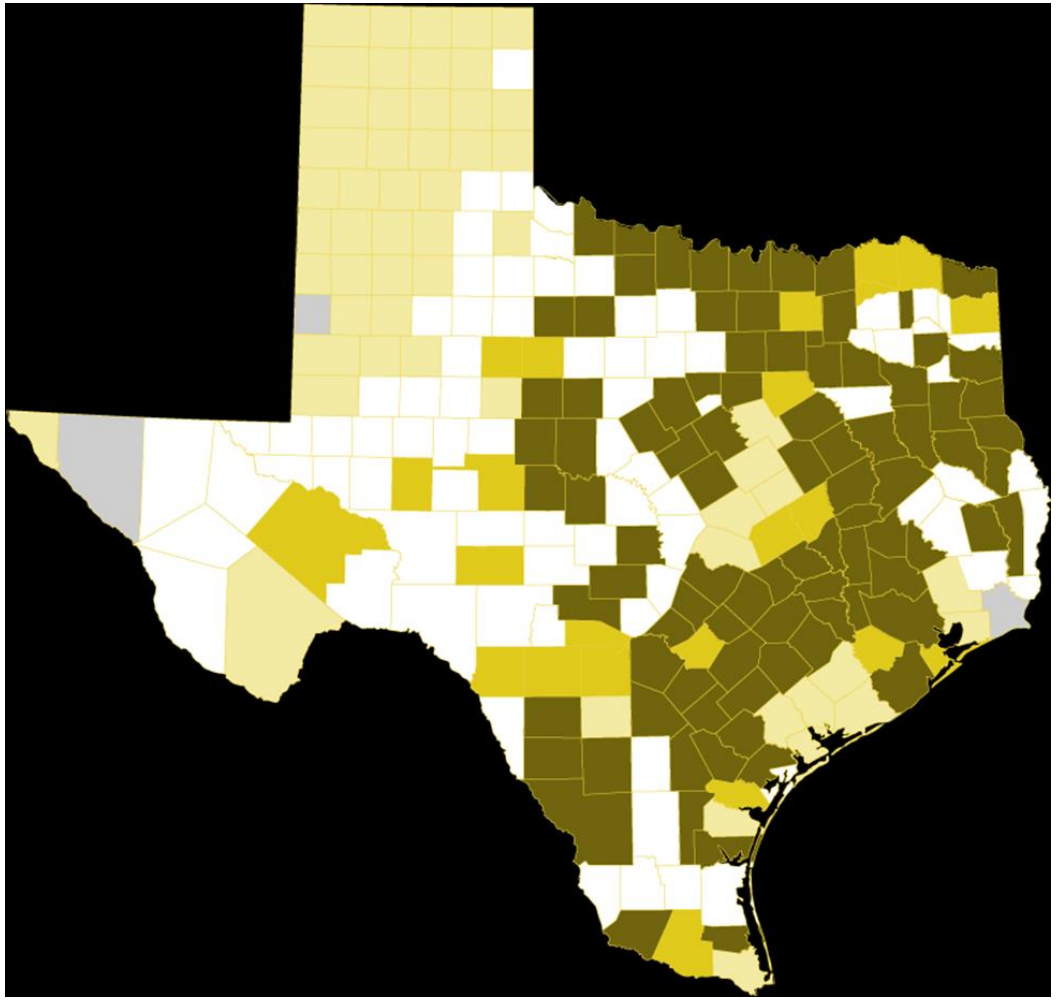
- Green: increase in yield; purple: severe decrease in yield up to 94%
- Corn and soy production is more sensitive to heat than drought, and it will decrease for every degree of warming.
- By midcentury, North Dakota, which already harvests millions of acres of both crops, will warm enough to allow for more growing days and higher yields. But parts of Texas and Oklahoma may see yields drop by more than 70%.

Pinal Co., Arizona. Harvesting a cob of blue corn that grew without kernels at Ramona Farms in August 2020

Corn and soy production will decrease with every degree of warming; by 2060, parts of Texas may experience a drop in yields of more than 92 percent

- **Crop yield decline by:**

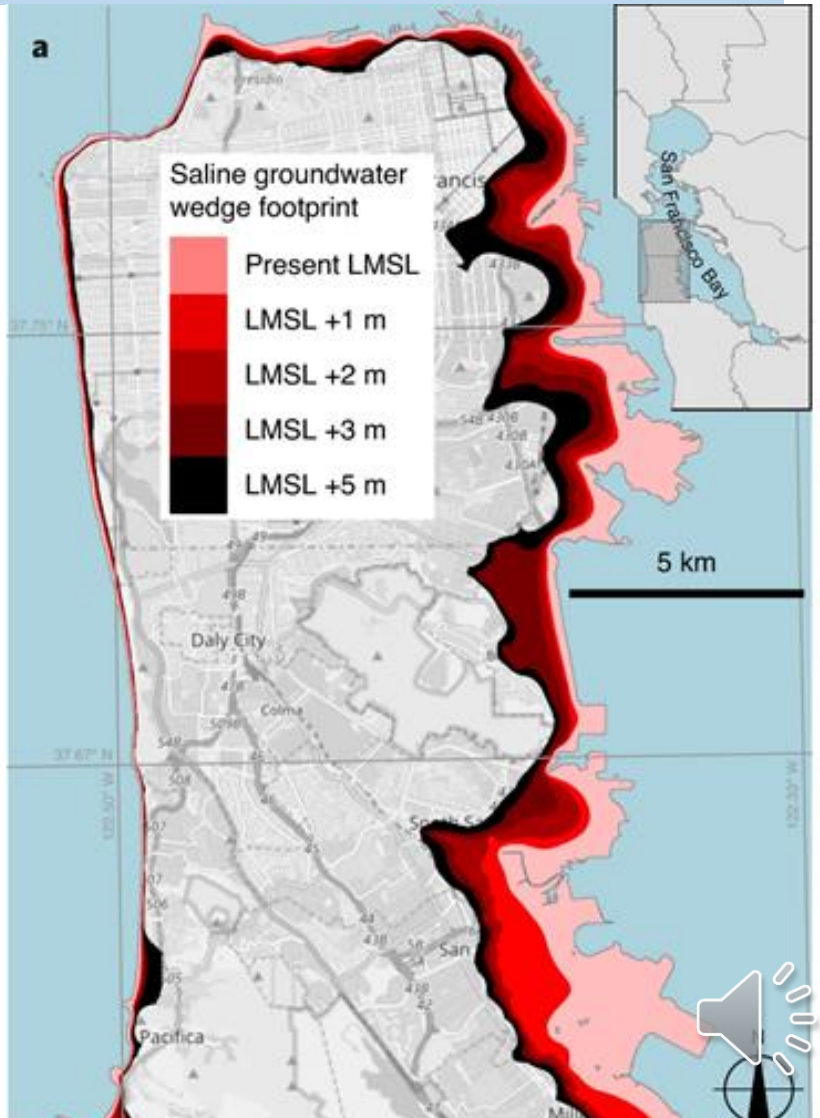
- **60–92%**
- **30–60%**
- **0–30%**
- **Yield increases**
- **No data**
- ***High Emissions scenario**
- **Darker more decline**



Increasing Threat of Coastal Groundwater Hazards from Sea-level Rise in California (Befus et al., 2020)

LMSL = local mean sea level

- Projected sea-level rise will raise coastal water tables, resulting in groundwater hazards that threaten shallow infrastructure and coastal ecosystem resilience.
- With 1 m of sea-level rise, areas flooded from below are predicted to expand ~50–130 m inland, and low-lying coastal communities such as those around San Francisco Bay are most at risk.
- Substantially increases risk of saltwater intrusion.
- All scenarios estimate that areas with shallow coastal water tables will shrink as they are inundated by overland flooding or are topographically limited from rising inland.



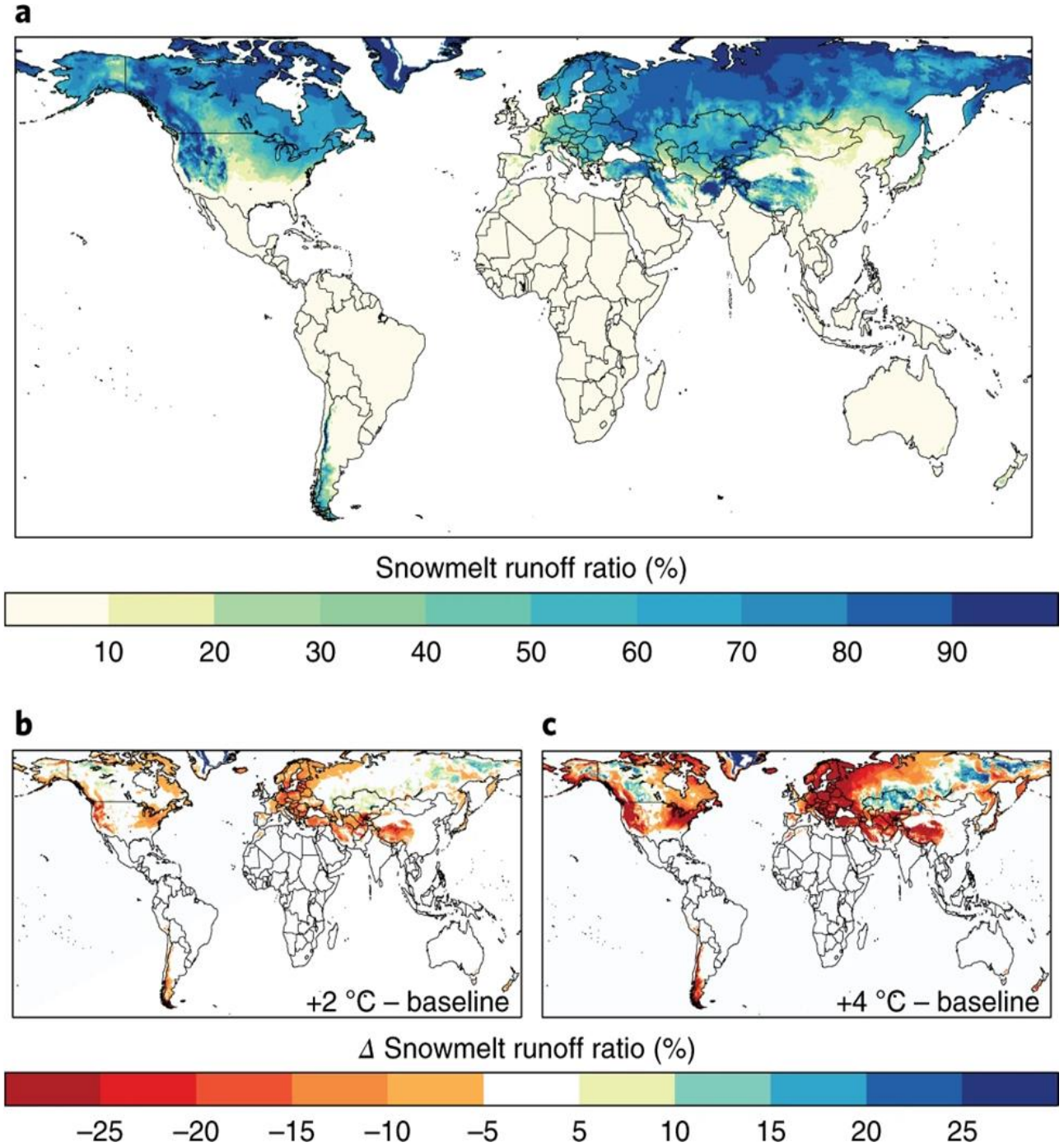
Impacts of Rising Temperatures and Farm Management Practices on Global Crop Yields (Agnolucci et al., 2020)

- Global statistical models examined the influence of weather and management practices on the yields of 18 crops, accounting for 70% of crop production by area and 65% by calorific intake.
- Irrigation was found to alleviate negative implications from temperature increases.
- Disproportionate impact: countries where increasing temperature causes the most negative impacts are typically the most food insecure, with the lowest calorific food supply and average crop yield.
- International action must be coordinated to raise yields in these countries through improvement and modernization of agricultural practices to counteract future adverse impacts of climate change.

Agricultural Risks from Changing Snowmelt (Qin et al., 2020)

- Snowpack stores cold-season precipitation to meet warm-season water demand.
- Climate change threatens to disturb this balance by altering the fraction of precipitation falling as snow and the timing of snowmelt, which may have profound effects on food production in basins where irrigated agriculture relies heavily on snowmelt runoff.
- At-risk areas are in high-mountain Asia (the Tibetan Plateau), Central Asia, western Russia, western US and the southern Andes.
- The basins most at risk from changing snowmelt patterns, where up to 40% of irrigation demand must be met by new alternative water supplies under a 4 °C warming scenario. Affected are basins and crops where adaptation of water management and agricultural systems may be especially critical in a changing climate.

By 2100, Greenland will be losing ice at its fastest rate in 12,000 years (Gramling, 2020)

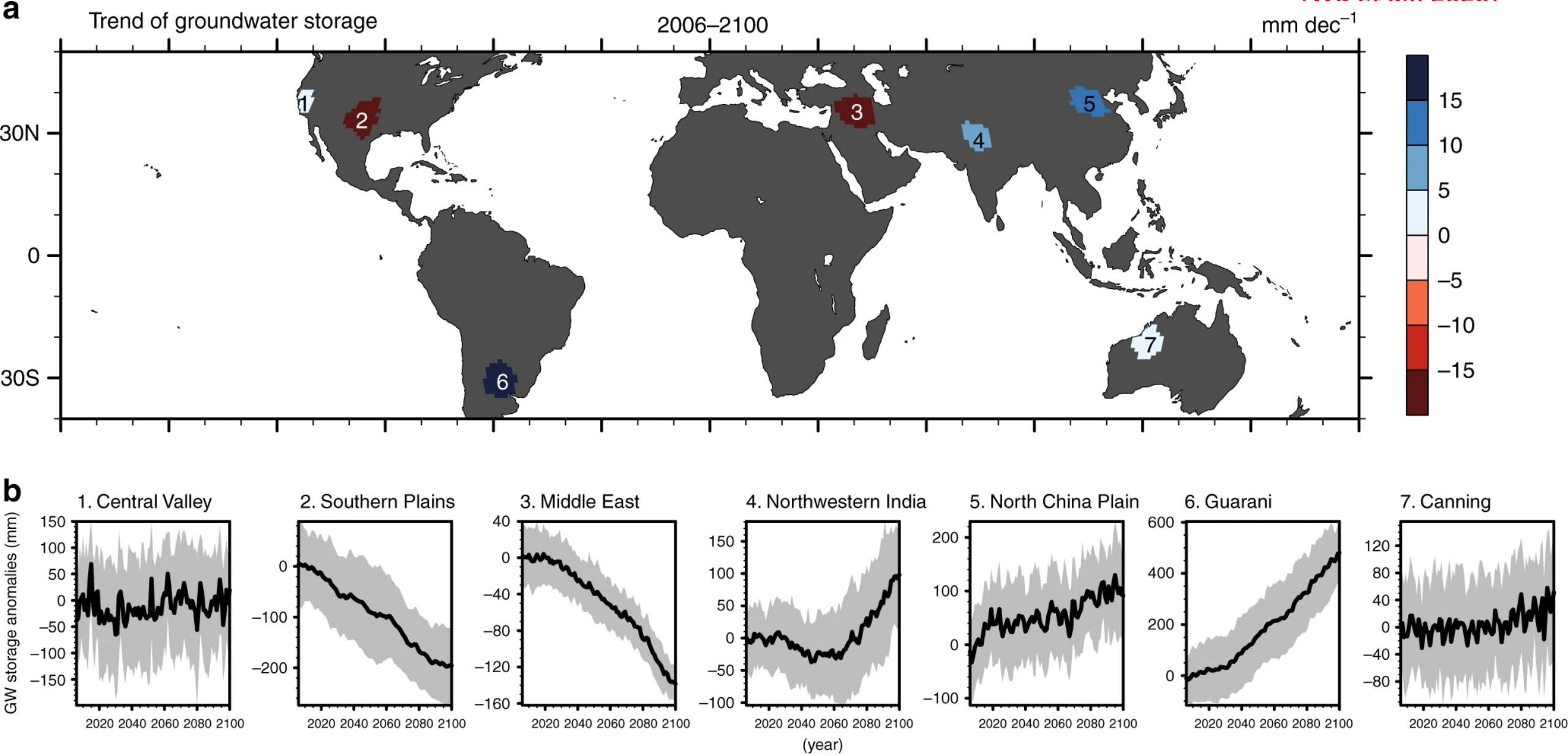


- a–c, Based on historical data, the average ratio of annual runoff from snowmelt (a) is >80% in many areas, especially in the higher latitudes of the Northern Hemisphere.
- Under warming of 2 °C (b) and 4 °C (c), the share of runoff originating from snowmelt declines substantially in many of the same areas (Qin et al., 2020).

Divergent Effects of Climate Change on Future Groundwater Availability in Key Mid-latitude Aquifers (Wu et al., 2020)

- Under the business-as-usual scenario (RCP8.5), the climate-driven impacts on ground water storage (GWS) changes enhance evapotranspiration, and reduction in snowmelt, which collectively lead to divergent responses of GWS changes across different aquifers (worst in western US and Middle East).
- The reduction in GWS is mainly due to the combined impacts of over-pumping and climate effects; however, the contribution of pumping could easily far exceed the natural replenishment.

(Wu et al., 2020)



The projected trends (2006–2100) of the climate-driven GWS changes under the RCP8.5 scenario (Wu et al., 2020).

Climate Change Effects on the Oceans and Fisheries

Projected Change in Global Fisheries Revenues Under Climate Change (Lam et al. 2016; Costello et al., 2020)

- The global fisheries sector supports the livelihoods of between 660 to 820 million people, directly or indirectly, which is about 10–12% of the world's population
- Global fisheries revenues could drop by 35% more than the projected decrease in catches by the 2050s under high CO_2 emission scenarios.
- Regionally, the projected increases in fish catch in high latitudes may not translate into increases in revenues because of the increasing dominance of low value fish, and the decrease in catches by these countries' vessels operating in more severely impacted distant waters.
- A shift to mariculture. Will a large increase in aquaculture products be accepted in the future?

Wrong-way Migrations of Benthic Species Driven by Ocean Warming and Larval Transport (Fuchs et al., 2020)

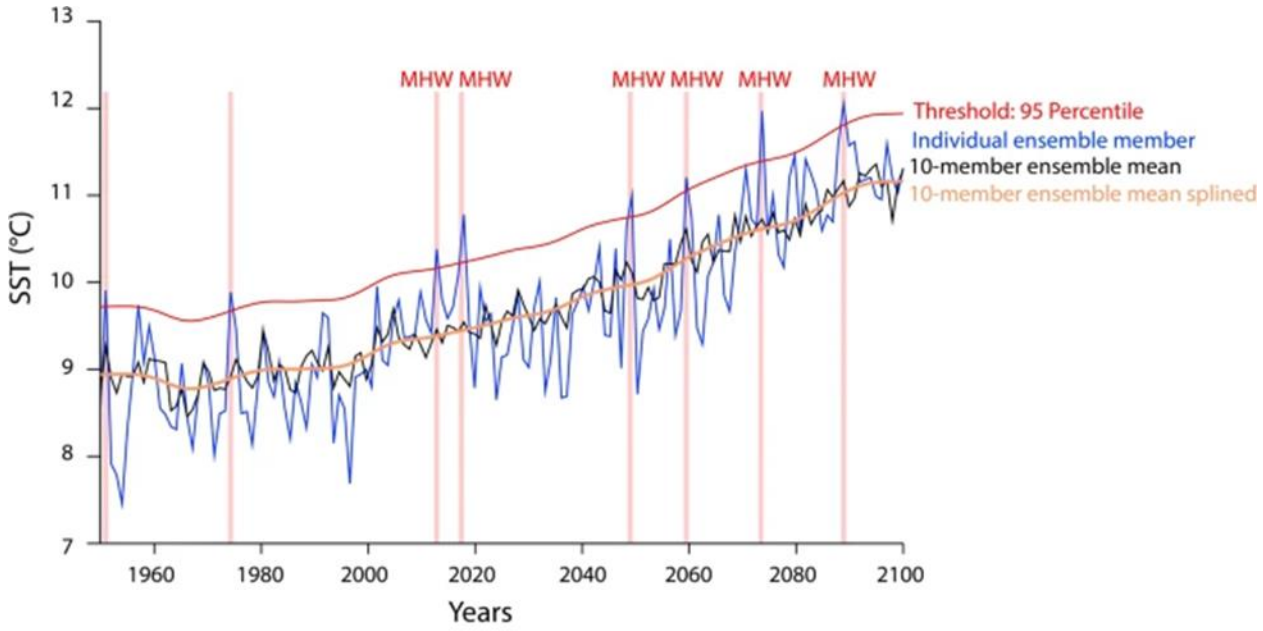
- Ocean warming has predictably driven fish to migrate as adults polewards or to deeper water to remain at tolerable temperatures.
- On the Northwest Atlantic continental shelf, however, many benthic invertebrates' ranges have instead shifted southwards and into shallower, warmer water.
- The larvae spawned earlier in the year encounter more downwelling-favourable winds and river discharge that drive transport onshore and southwards. This study reveals a physical mechanism that counterintuitively pushes benthic species, including commercial shellfish, into warmer regions with higher mortality.
- As climate change reduces yields from traditional fisheries, the seafood industry may rely more heavily on invertebrates, including clams and mussels, but their spawn is at low temperatures, and their ranges have warmed and contracted.

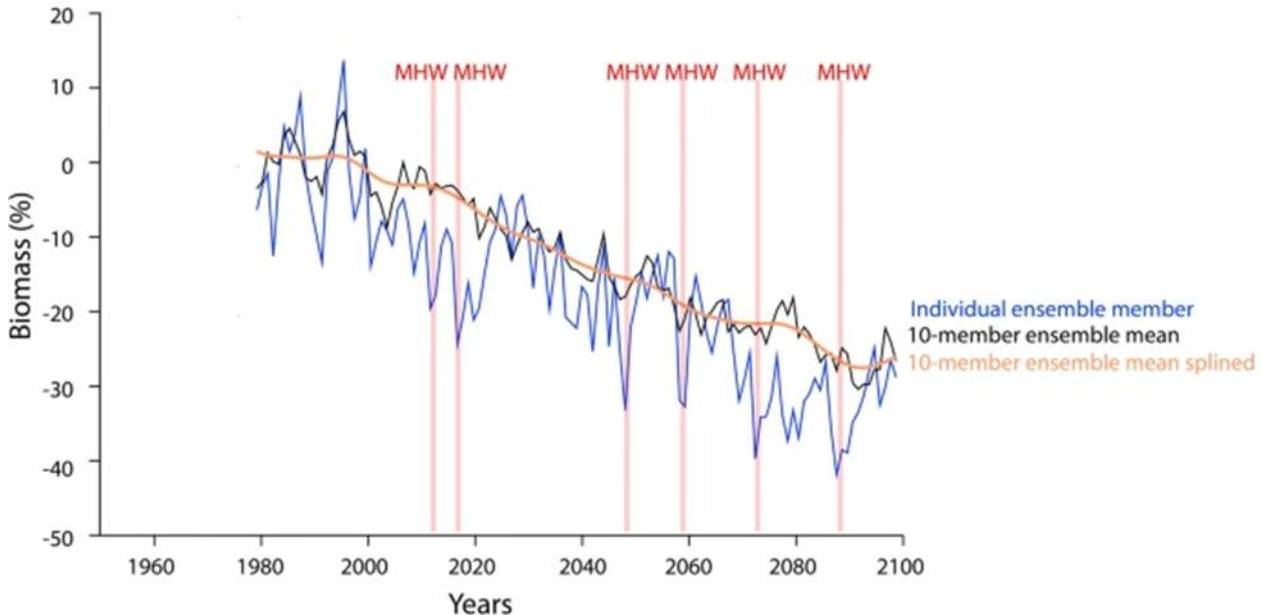
Recent Declines in Salmon Body Size Impact Ecosystems and Fisheries (Oke et al., 2020)

- Widespread declines in Pacific salmon size based on 60 years of measurements from 12.5 million fish across Alaska.
- Declines in salmon size are associated with climate and competition at sea.
- For Chinook salmon estimated average per-fish reductions in egg production (−16%), fisheries value (−21%), and meals for rural people (−26%).
- Climate warming might also reduce ectotherm body size by increasing metabolic and developmental rates.
- These environmental factors could result in increased natural mortality in the ocean, leading to reduced average age-at-return to freshwater.

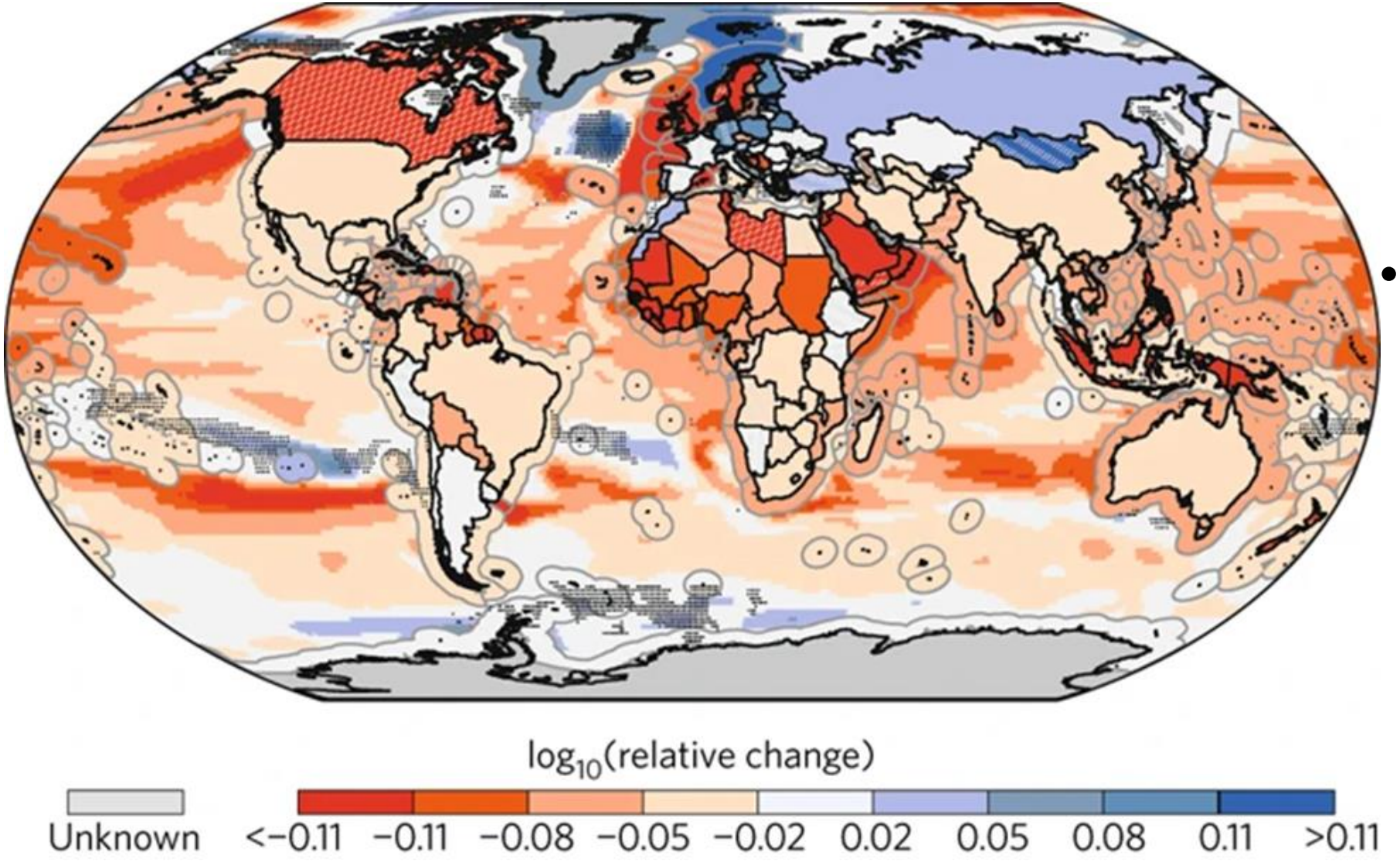
Keeping Pace with Marine Heatwaves (Holbrook et al., 2020)

- Marine heatwaves (MHWs) are prolonged extreme oceanic warm water events.
- They can have devastating impacts on marine ecosystems — for example, causing mass coral bleaching and substantial declines in kelp forests and seagrass meadows — with implications for the provision of ecological goods and services.
- Effective adaptation and mitigation efforts by marine managers can benefit from improved MHW predictions, which at present are inadequate.





- Top. Predicted rising sea surface temperature (SST) with marine heatwaves (MHW, persistent extremely warm ocean temperatures, called 'Blobs' under RCP 8.5
- Bottom. MHW impacts on biomass of the sockeye salmon (Oncorhynchus nerka) in the Gulf of Alaska large marine ecosystem.
- The red vertical bars in both panels indicate MHW events.
- By 2050 MHWs will double their impact levels amongst the most important fisheries species challenging fisheries management (Cheung and Frölicher, 2020).

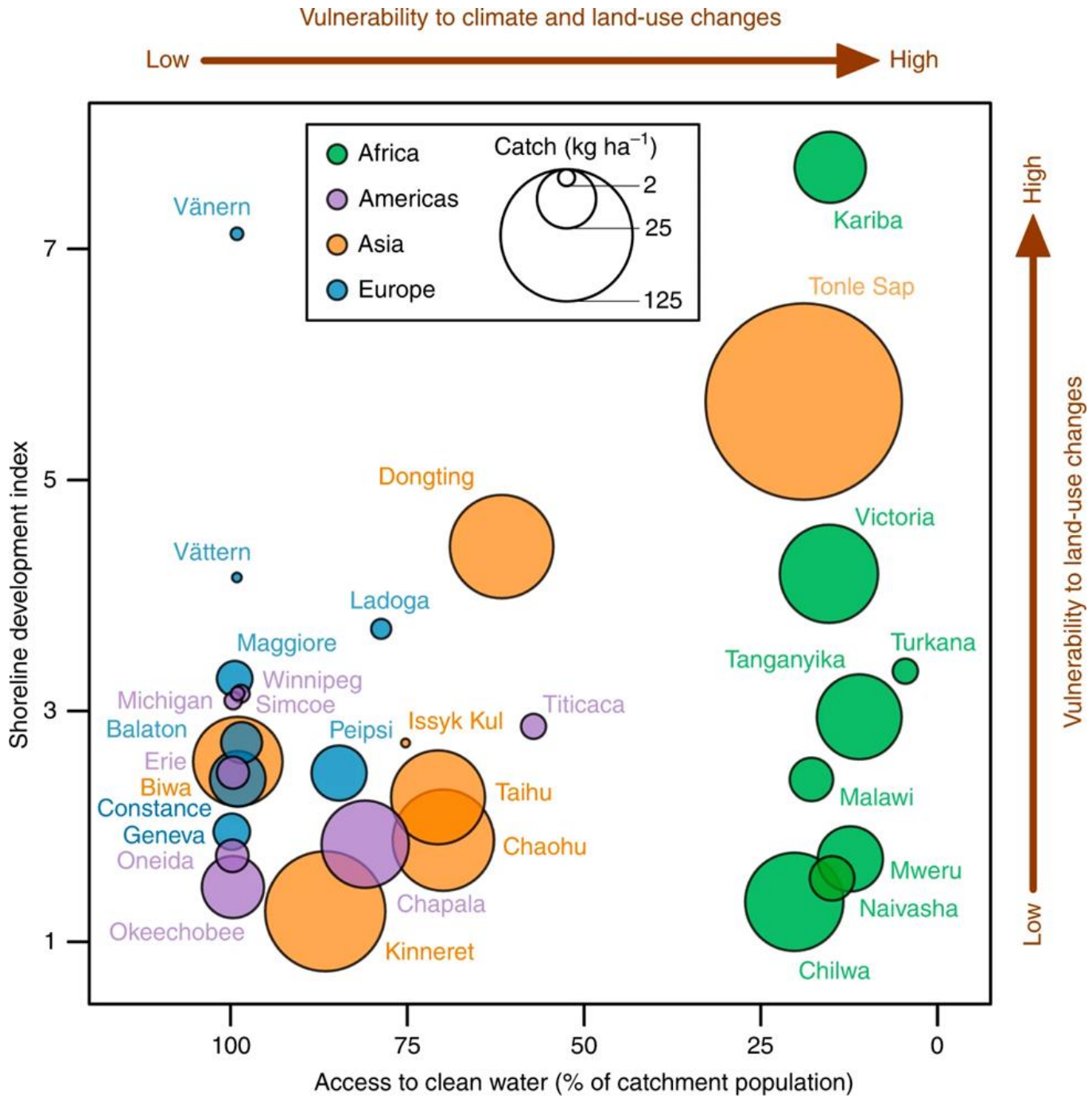


- Projected relative changes in potential crop (maize, wheat, rice and soy combined) and fish production (RCP6.0 scenario)

Some countries are likely to face double jeopardies in both fisheries and agriculture sectors under climate change (Blanchard et al., 2017)

Climate Change Impacts on the Biophysics and Economics of World Fisheries (Sumaila et al., 2011)

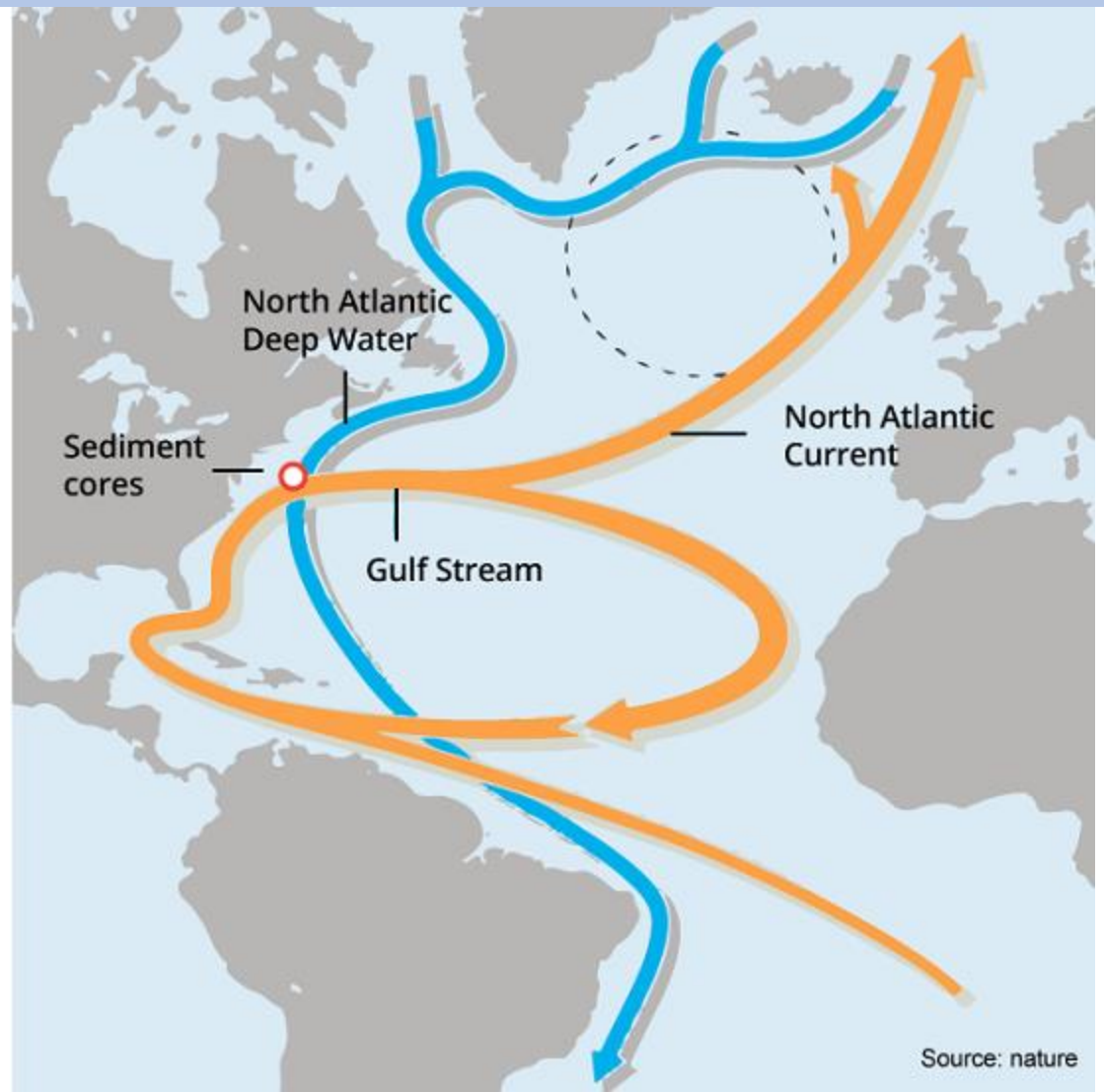
- Ecological changes that are considered to be related to climate change
  - Shift in distribution of species in Arctic, Temperate, Tropics
  - Increased uncertainty in predator-prey dynamics
  - Ocean acidification
  - Expansion of oxygen minimum zones
  - Reduction in body size
  - Increased extreme weather



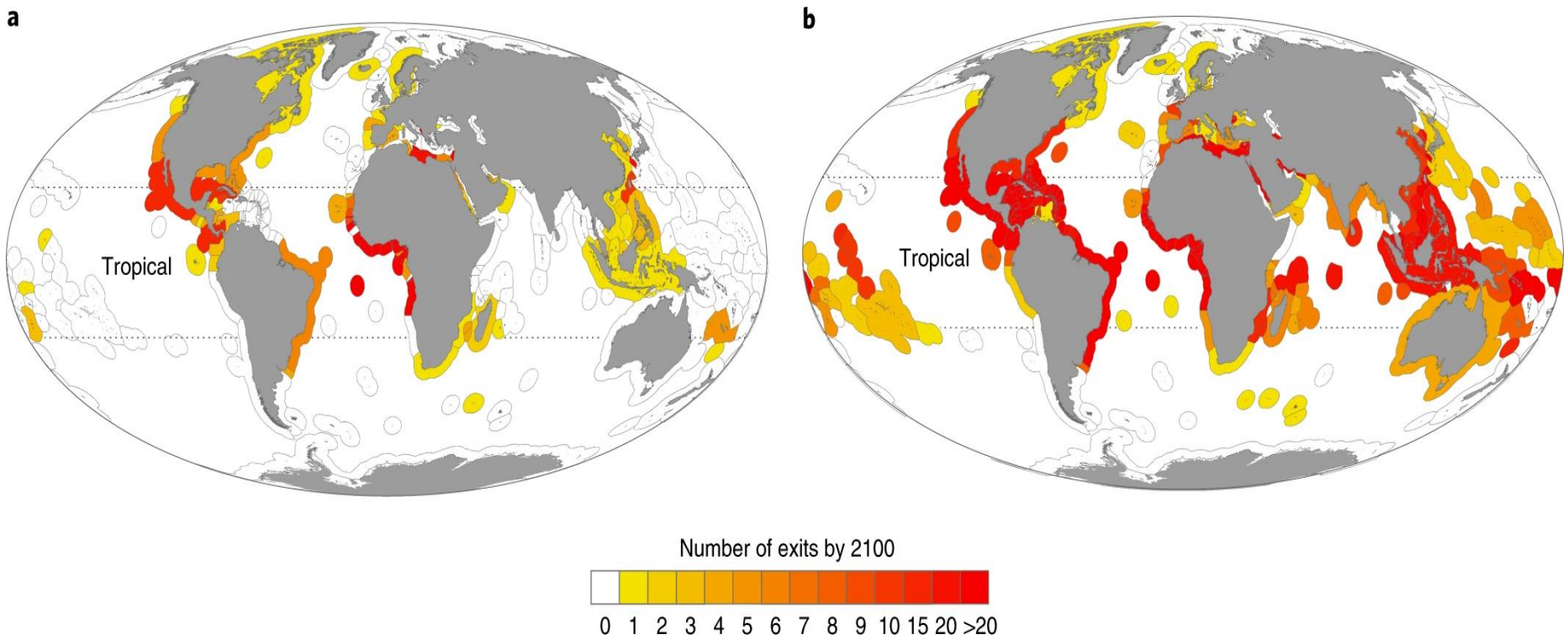
- The area of each circle is proportional to the median fish catch in the period 1970–2014.
- Lakes located in areas with lower access to clean water are more vulnerable to substantial decreases in fish catches driven by either climate or land-use change and lakes with larger shoreline development index are more vulnerable to substantial decreases in fish catches driven by land-use change.

Kao et al., 2020

The Atlantic Meridional Overturning Circulation (AMOC)

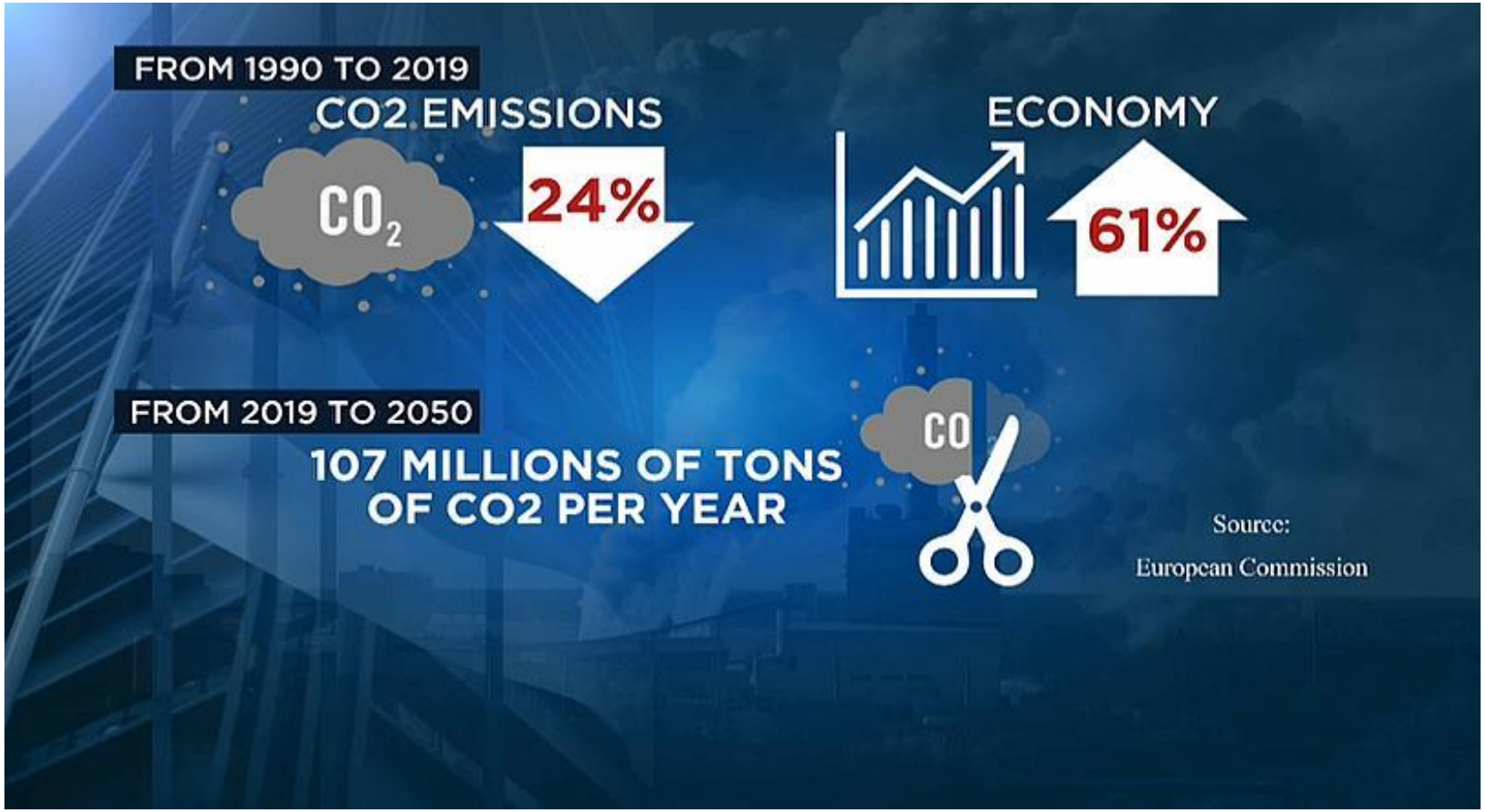


- AMOC carries up to 25% of the northward global atmosphere-ocean heat transport in the northern hemisphere.
- The AMOC is essential for communities, agriculture and fisheries in Western Europe.
- While a shutdown is deemed “unlikely” by the IPCC, a weakening over the 21st century is assessed as “very likely”.
- The cause of future weakening in models is a combination of surface freshening due to changing precipitation patterns in the North Atlantic and glacial melt, and greenhouse-gas induced warming from



- a, b, the number of commercial fish species shifting out of each EEZ (exclusive economic zone) by 2100 under RCP 4.5 (a) and RCP 8.5 (b) (Oremus et al., 2020). The risk is particularly acute in the tropics, where projected exits are highest and entries are fewest.

The EU has Ambitious Plans to Cut GHG



- Goal: 55-60% reduction in greenhouse gas emissions by 2030, compared to levels in 1990.
- Is it achievable?
- What about the rest of the world?

Conclusions

- The amount of climate change research is vast and increasing with many publications in 2020.
- Climate change research is based on observations and modeling to create a variety of scenarios with many possible inputs and outputs.
- The models are based on global policy changes to reduce GHG from Representative Concentration Pathways of no CO_2 emissions by 2100 to business as usual (RCP2.6 - RCP8.5).
- Immediate effects are droughts, wildfires, flooding, hurricanes, and less land for agriculture and fish species to harvest.
- Longer term possible effects are mass migrations, increased urbanization, mass hunger and poverty, plus weakening of the Atlantic Meridional Overturning Circulation.