

IMPACTS of Global Warming at 2.0 °C

Potential IMPACTS of Global Warming at **2.0 °C**

References:

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<https://www.wri.org/insights/2023-ipcc-ar6-synthesis-report-climate-change-findings>

<https://www.nature.com/articles/s41598-022-22228-7>

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9621323/>

What is our likely

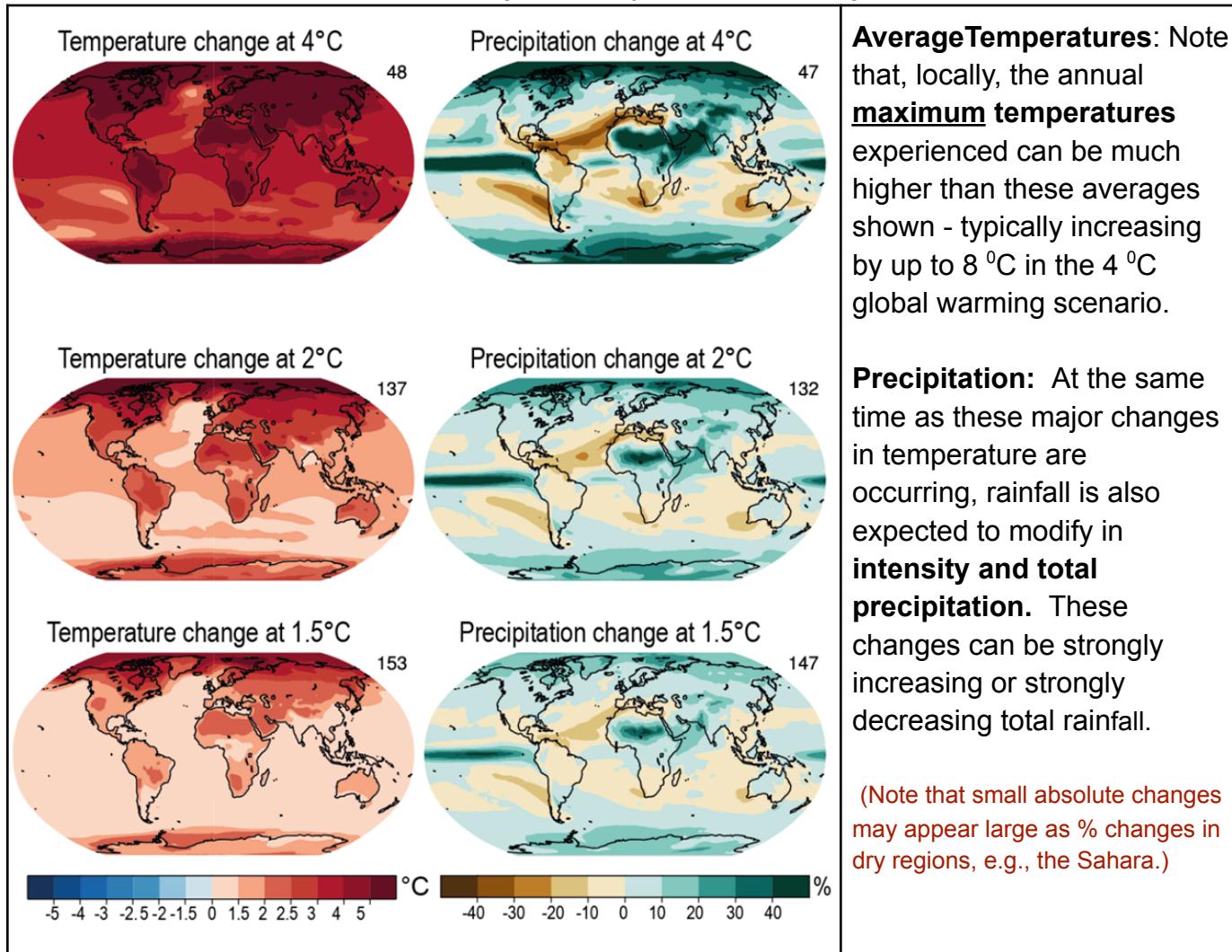
Near-Term (within $15\pm$ years) Future from Human-Caused Global Warming [If we don't cut Emissions radically]

IMPACTS of Global Warming at 2.0 °C

The 1.5 °C graphics in these charts can be considered our current condition. The 2.0 °C graphics are likely near-term futures and the focus of this present study.

1. SURFACE TEMPERATURE and PRECIPITATION CHANGES THE TRENDS

Average Warming (relative to the period 1850-1900) is shown, with even greater warming toward the poles and specific areas. Dramatic climate changes are projected all over the globe as temperatures rise.



IMPACTS of Global Warming at 2.0 °C

SURFACE TEMPERATURE and PRECIPITATION

SPECIFIC Additional IMPACTS at 2.0 °C

- **heatwaves** that, on average, arose once every 10 years will likely occur over 5 times more frequently, and their **intensities** will increase.
- Steady **increases of temperatures of annual hottest days**
- **37% of global population exposed to severe heat at least once every 5 years** (vs. 14% at 1.5 C)
- Widespread **increases of annual wettest-day precipitations**
- **Increasing heavy precipitation and flooding events** expand to more regions and/or become more significant (high confidence) and **more frequent and/or severe agricultural and ecological droughts** are projected for Europe, Africa, Australasia, and North, Central, and South America (medium to high confidence).
- **Direct flood damages** are higher by 1.4 - 2 times over 1.5 C without adaptation (medium confidence)
- 2°C – and even 1.5°C – is too high to prevent **extensive permafrost thaw and resulting CO2 and methane emissions** that will cause temperatures to continue to rise. These emissions are irreversibly set in motion and will not slow for 1–2 centuries, meaning that future generations must offset them (draw down carbon) at scales probably total the size of the entire European Union's emissions from 2019 or more.
- **Intensification of tropical cyclones and/or extratropical storms** (medium confidence), and **increases in aridity and fire weather** (medium to high confidence).
- **Compound heatwaves and droughts** become likely more frequent, including concurrently at multiple locations (high confidence).

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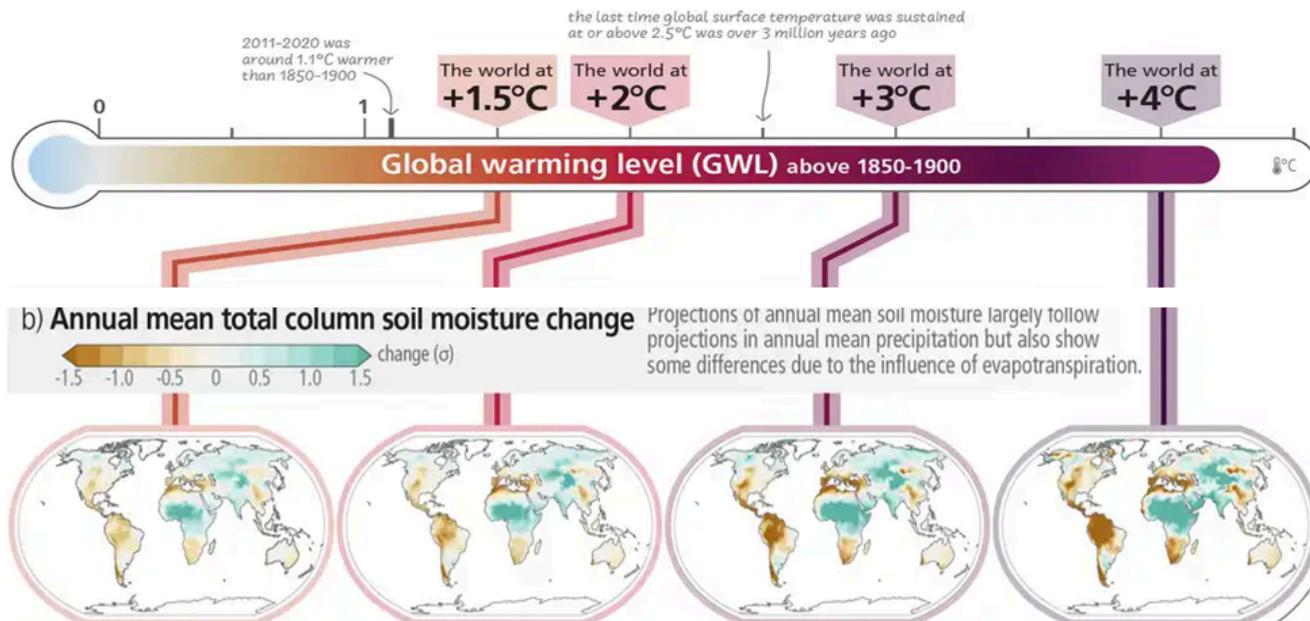
- Due to **unavoidable sea level rise**, risks for coastal ecosystems, people, and infrastructure will continue to increase beyond 2100 (high confidence).



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2. SOIL MOISTURE and FOOD PRODUCTION THE TRENDS

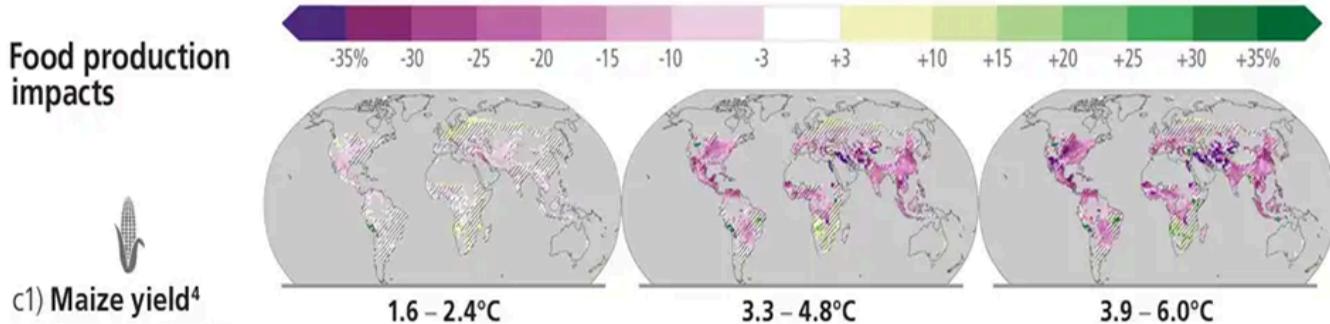
SOIL MOISTURE: With major changes in rainfall, in combination with the increased heat, the moisture in the soil for plant growth can take significant hits. (Note that small absolute changes may appear as large changes in dry regions, e.g., the Sahara.)



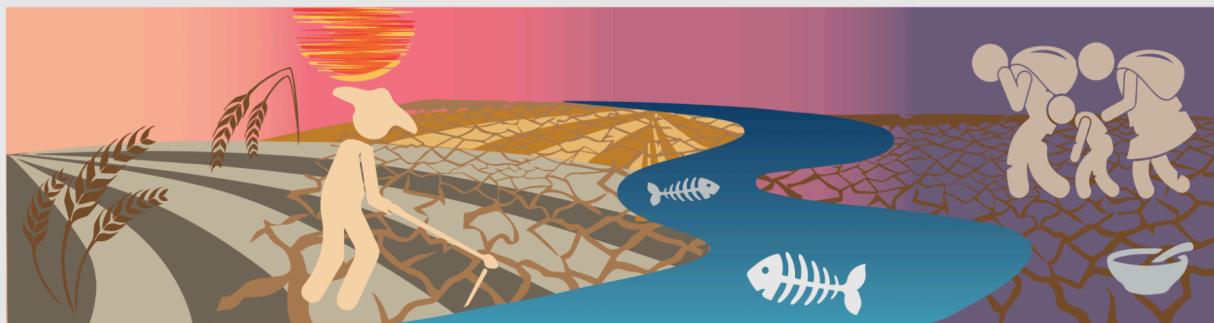
Notable regions include the US Southwest, Europe and the Mediterranean, Central America, and the Amazon.

FOOD PRODUCTION: As more regions become less habitable to humans and diverse species, food production will be more challenging. The change in % yield of Maize provides one example.

IMPACTS of Global Warming at 2.0 °C



IMPACTS ON FOOD AT...



1.5°C

Wheat, rice, maize
and soybean production
suffers

2.0°C

Agricultural yields
fall rapidly

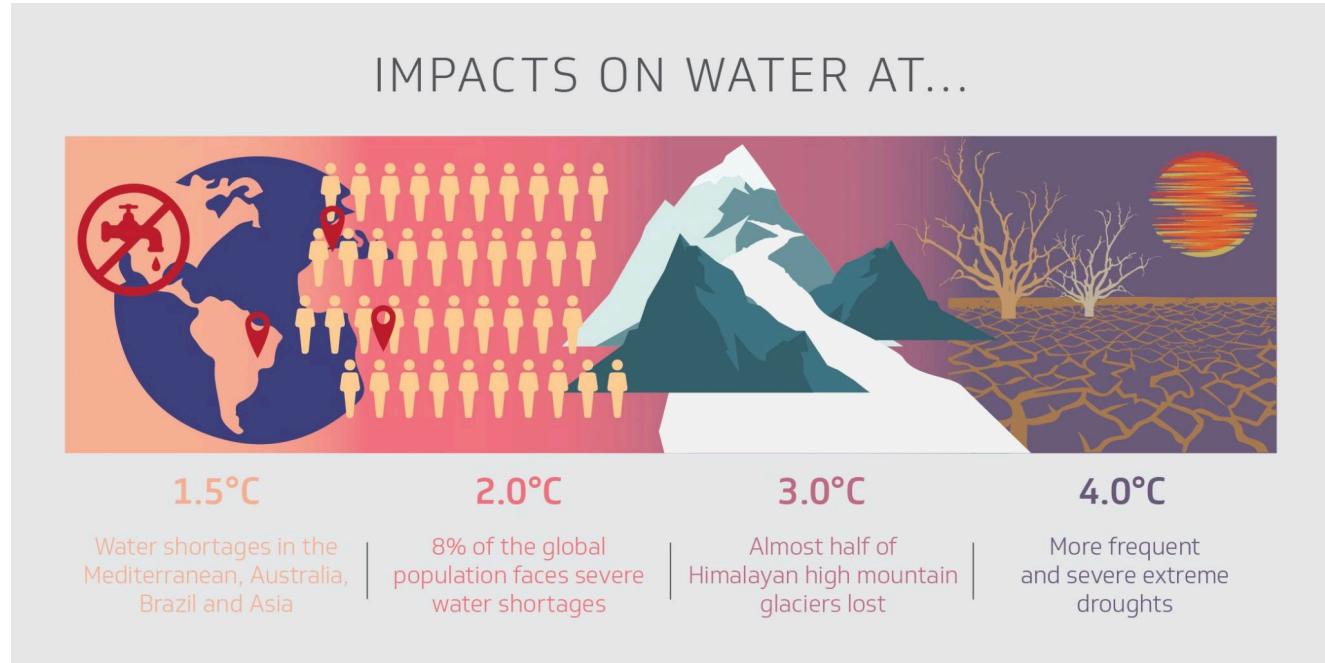
3.0°C

Fish species go
extinct locally

4.0°C

High levels of food
insecurity, development
path reversed

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SOIL MOISTURE and FOOD PRODUCTION

SPECIFIC Additional IMPACTS at 2.0 °C

- Agricultural yields fall rapidly. **Maize production** drops around 11%, with similar losses in wheat and rice.
- 8% of the global population face severe water shortages.
- **Intensifying changes in annual mean total column soil moisture** (Note that small absolute changes may appear large as % changes in dry regions, e.g., the Sahara.)
- **nearly all tropical glaciers** (north Andes, Africa) and **most mid-latitude glaciers** outside the Himalayas and polar regions **will disappear**, some as early as 2050. The **Himalayas lose around 50% of today's ice**.

IMPACTS of Global Warming at 2.0 °C

- **As glaciers melt, risks of catastrophic events will rise** – landslides, sudden ice shears, and in some cases glacial lake outburst floods, affecting entire communities.
- **Winter snowpack generally will decrease, but also become more volatile**; with some years of hardly any snow, and others with record-breaking amounts that threaten infrastructure and lives.
- Losses in both snowpack and glacier ice will have **dramatic impacts on downstream dry season water availability** for agriculture, power generation, and drinking.
- Year-round, essentially **permanent corrosive ocean acidification** conditions in extensive regions of Earth's polar and some near-polar seas; with **widespread negative impacts on key fisheries and species**.
- **Shell-building animals, and commercial fisheries that rely on them** in the food chain – valuable species such as krill, cod, salmon, lobsters, king crab, to name just a few – **may not survive in the wild or when cultivated** in these corrosive waters.
- These “overshoot” **corrosive conditions**, set by peak atmospheric CO₂ levels, are essentially **irreversible, lasting 30–70,000 years**.
- 3 Million tonnes reduction in sea fishing. (2x the 1.5 C impact).

IMPACTS of Global Warming at 2.0 °C



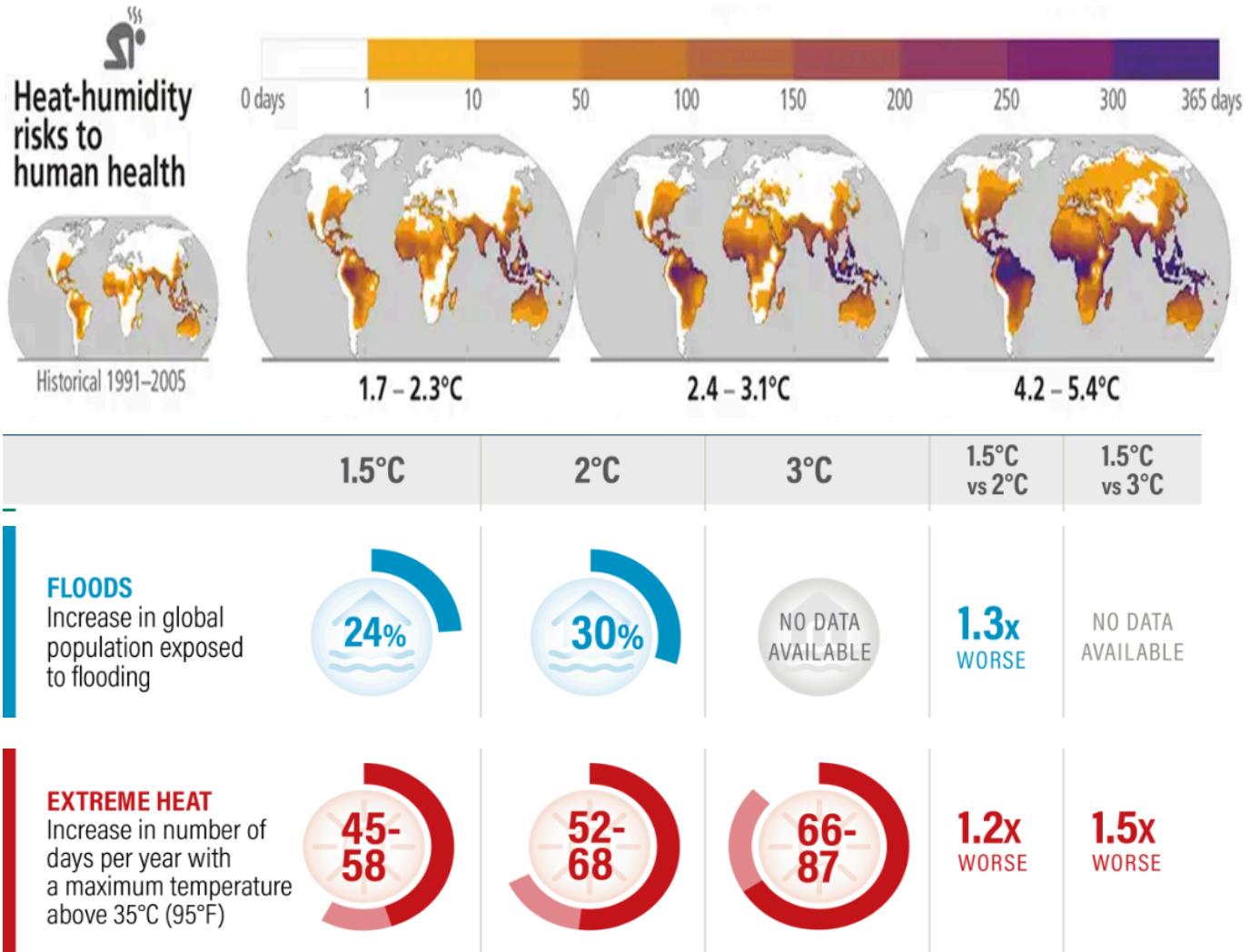
<https://www.foodbusinessnews.net/articles/19120-drought-heat-wreak-havoc-on-western-crops>

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3. HEAT-HUMIDITY RISKS TO HUMAN HEALTH THE TRENDS

These **temperature increases, combined with humidity**, will have direct effects on humans. More areas will become less habitable as the number of dangerous days in the year increase, posing a risk of mortality increase.

Days per year where combined temperature and humidity conditions pose a risk of mortality to individuals:



IMPACTS of Global Warming at 2.0 °C

HEAT-HUMIDITY RISKS TO HUMAN HEALTH

SPECIFIC Additional IMPACTS at 2.0 °C

- **1.15 billion persons** in dryland populations exposed to **water stress, heat stress, and desertification** (vs. 0.95 billion persons at 1.5 C)
- **Human mortality and morbidity have increased in all regions** from increases in **extreme heat** (very high confidence). **37% of the population exposed to heatwaves** and their consequences at least every 5 years.(more than 2x the 1.5 C impact)
- Climate-related changes in food availability and diet quality are estimated to **increase nutrition-related diseases and the number of undernourished people, affecting tens** (under low vulnerability and low warming) **to hundreds of millions of people** (under high vulnerability and high warming)
- Approximately **3.3 to 3.6 billion people** live in contexts that are **highly vulnerable** to climate change (high confidence). Climate and weather extremes are **increasingly driving displacements**.
- Increasing weather and climate extreme events have exposed millions of people to acute food insecurity and reduced water security (high confidence). **410 million persons in urban settings exposed to drought and water shortages** (14% increase from 1.5.C)
- **Climate change** has adversely affected human physical health globally and mental health (very high confidence), and is **contributing to humanitarian crises** where climate hazards interact with high vulnerability (high confidence).
- Due to **unavoidable sea level rise, risks** for coastal ecosystems, people, and infrastructure will continue to **increase beyond 2100** (high confidence).
- Climate-related **risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase**

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HUMID HEAT IMPACTS HEALTH

<https://www.climatecentral.org/climate-matters/high-heat-index-days-2023>

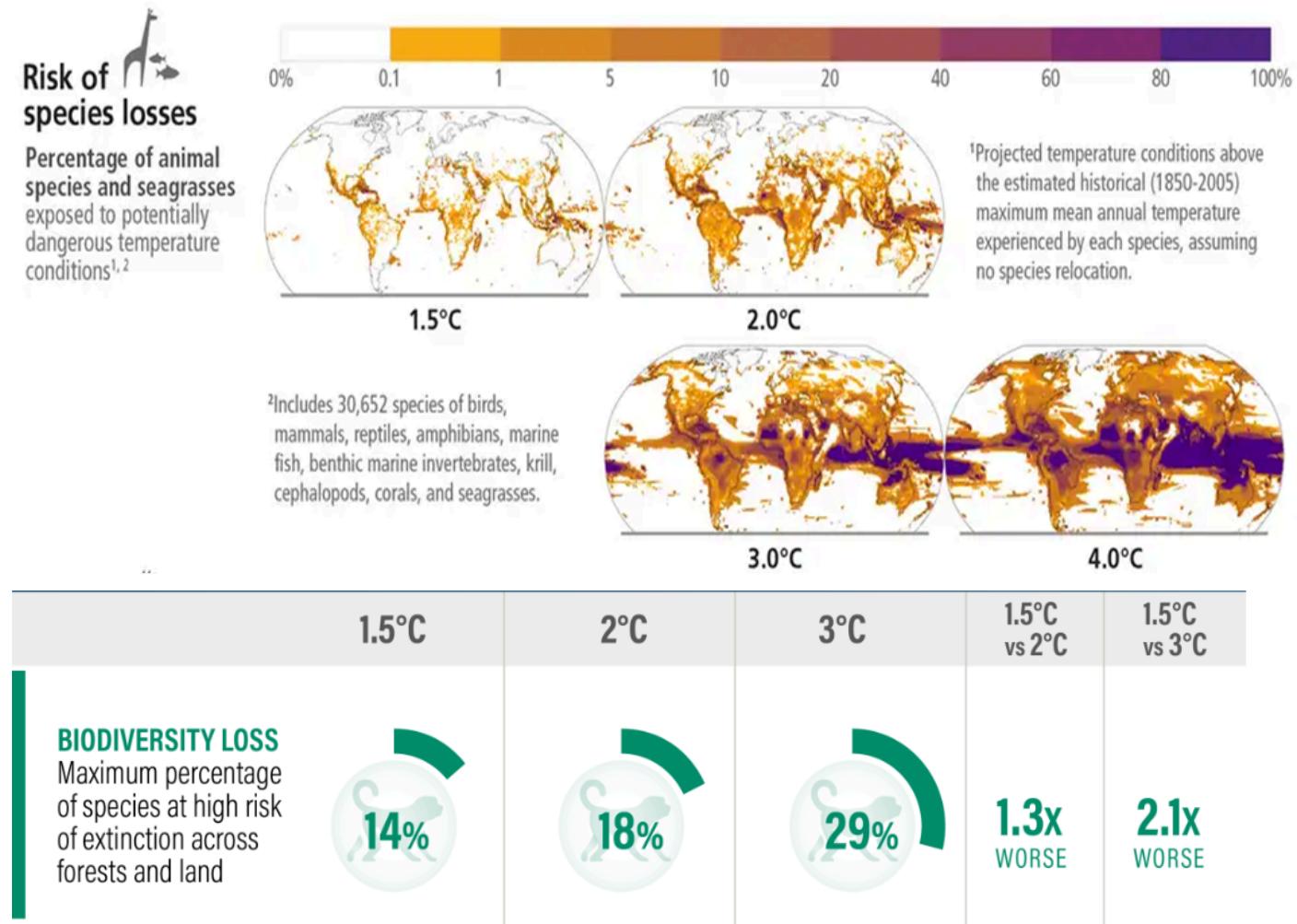
https://www.upi.com/Science_News/2023/04/27/Somalia-Africa-drought-climate-change/3331682606599/

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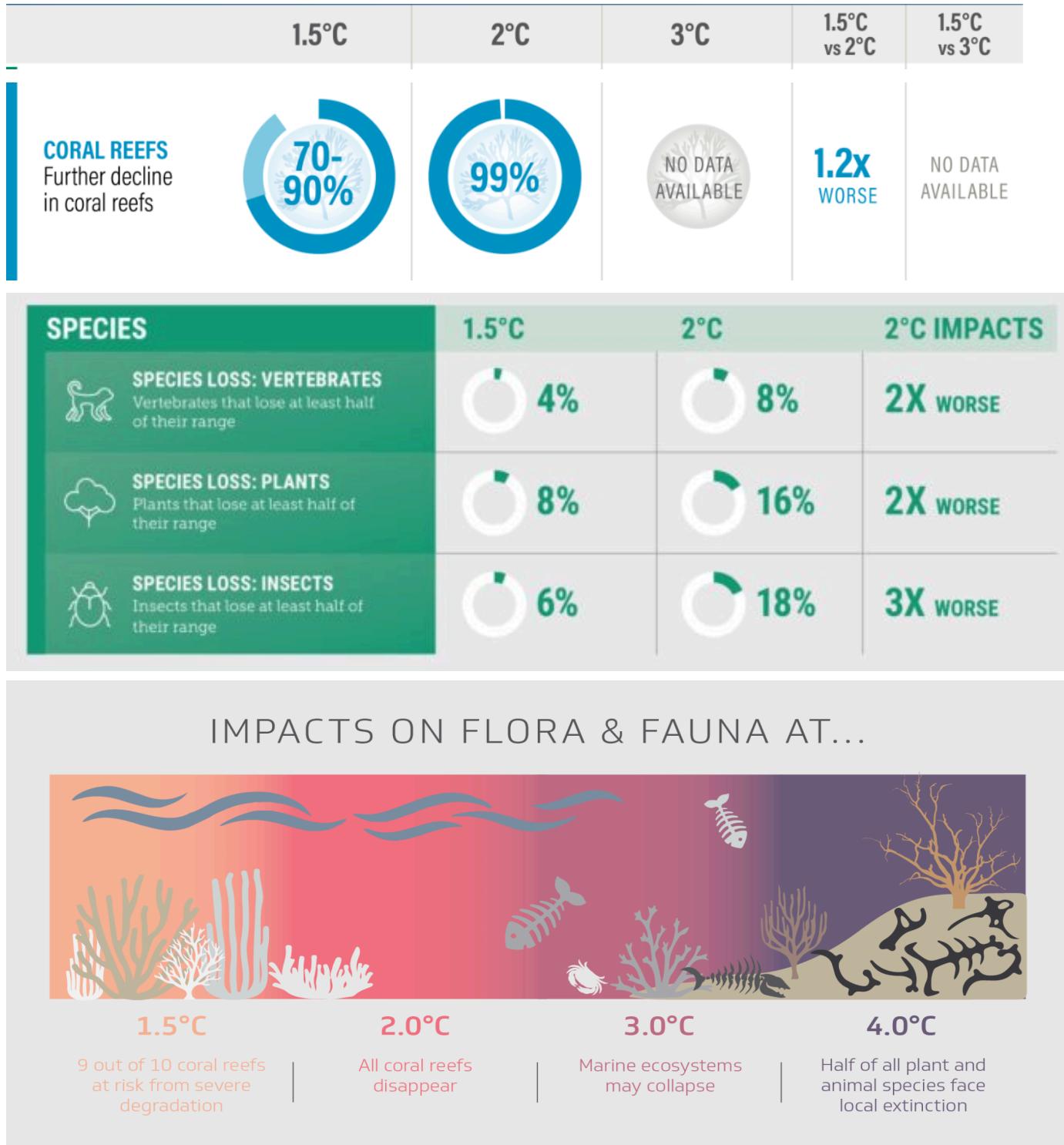
4. SPECIES EXTINCTIONS THE TRENDS

Not only will humans be displaced, but rising temperatures will increasingly require **species to relocate or die**.

These species include a broad selection of birds, mammals, reptiles, amphibians, marine fish, benthic (near-bottom) marine invertebrates, krill, cephalopods, corals, and seagrass. Risks of species losses are assessed by looking at projected temperature conditions as they are likely to be above the historical (1850-2005) maximum mean annual temperature experienced by each species, assuming no species relocation.



IMPACTS of Global Warming at 2.0 °C



IMPACTS of Global Warming at 2.0 °C

SPECIES EXTINCTIONS

SPECIFIC Additional IMPACTS at 2.0 °C

- **18% of the 30,652 species** assessed likely face a **very high risk of extinction**. At least 8 % of vertebrate animal species would be halved (2x the 1.5 C impact). 16 % of plants would lose half their numbers (2x the 1.5 C impact). 18% of insects would lose half their numbers (3x the 1.5 C impact). 13% of land area where ecosystems would change their characteristics, flora and fauna (almost 2x the 1.5 C impact).

The **biodiversity loss** we would suffer through an increase of 1.5°C would be catastrophic, but if the rise were to be in the order of **2°C**, the problem would be completely irreversible due to the disappearance of plant, animal and insect species, including the death of practically all coral reefs.

- **Very high extinction risk for endemic species** in biodiversity hotspots is projected to increase at **least tenfold over 1.5 C** (medium confidence).
- **99% of coral reef loss** worldwide (29% increase from 1.5 C impact).

IMPACTS of Global Warming at 2.0 °C



<https://www.wilderness.org/articles/blog/what-extinction-crisis-5-key-facts>

Heat and humidity can have a direct and devastating effect.

Mexico's howler monkeys dropping dead as heat toll mounts



<https://www.msn.com/en-us/news/world/mexico-s-howler-monkeys-dropping-dead-as-heat-toll-mounts/ar-BB1mK0BQ>

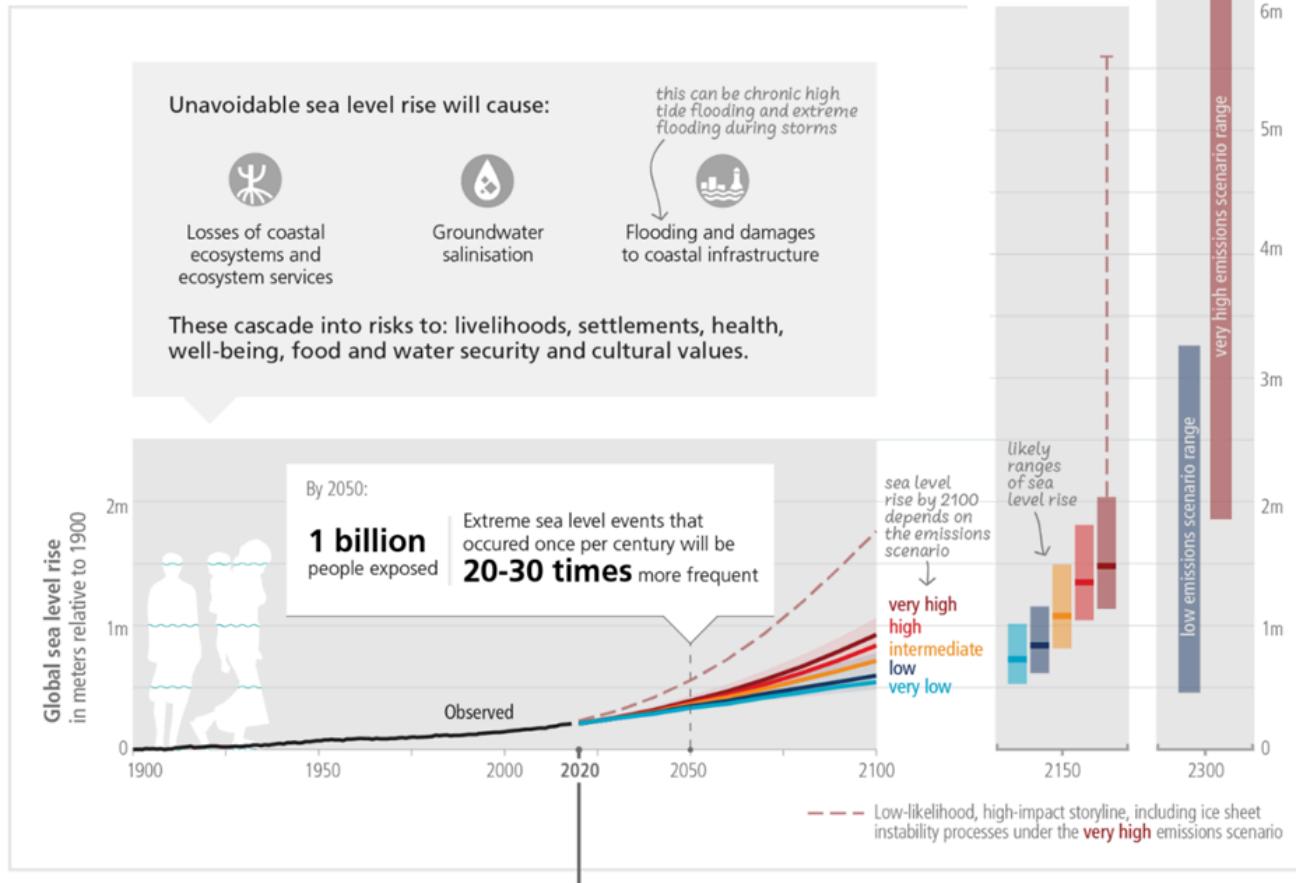
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5. SEA LEVELS THE TRENDS

Sea level rise is very much in our future.

Sea level rise will continue for millennia, but how fast and how much depends on future emissions

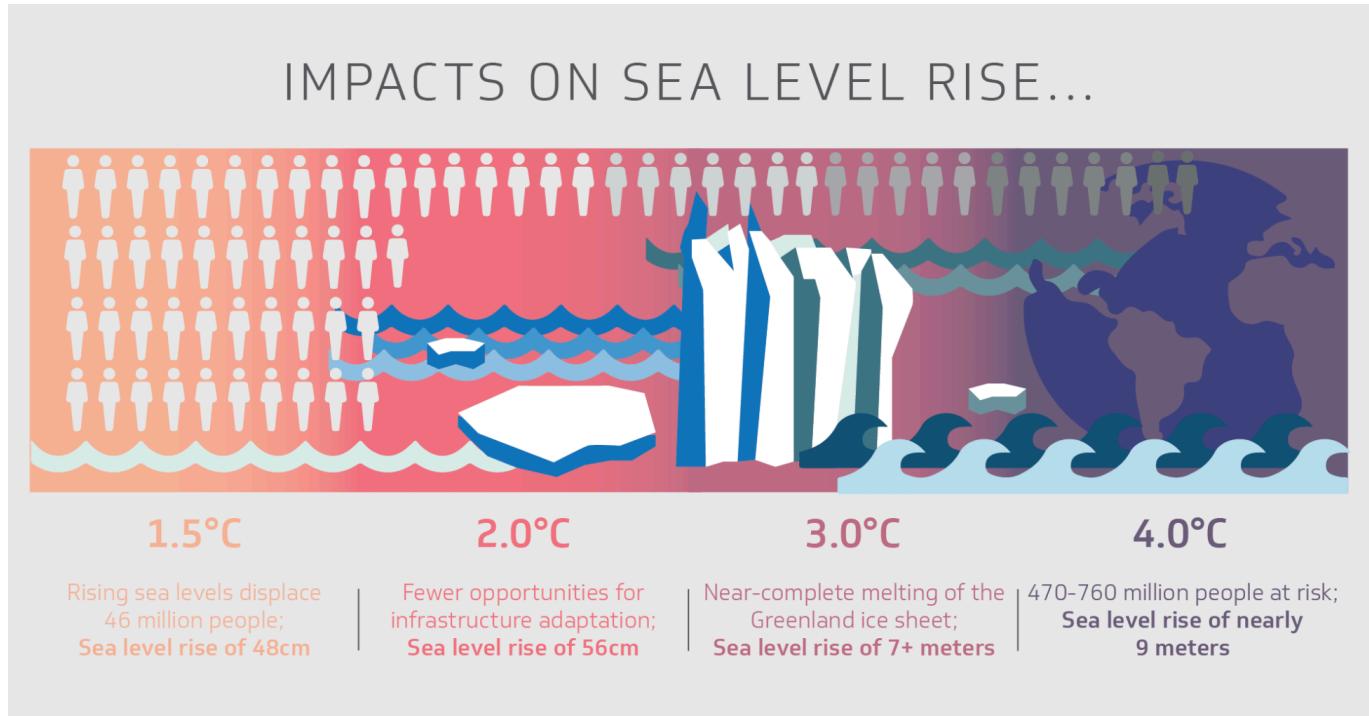
a) Sea level rise: observations and projections 2020-2100, 2150, 2300 (relative to 1900)



Recent publications have documented faster-than-expected melting in Greenland and Antarctica. Also, improved understanding of ancient (paleo) processes have been articulated. These raise the possibilities that the planet is more sensitive to changes in greenhouse gas concentrations. If so, sea levels may be significantly higher in this century than shown above.

IMPACTS of Global Warming at 2.0 °C

	1.5°C	2°C	3°C	1.5°C vs 2°C	1.5°C vs 3°C
SEA LEVEL RISE Global mean sea level rise by 2100	0.28-0.55m	0.33-0.61m	0.44-0.76m	1.1x WORSE	1.4x WORSE



IMPACTS of Global Warming at 2.0 °C

SEA LEVELS

SPECIFIC Additional IMPACTS at 2.0 °C

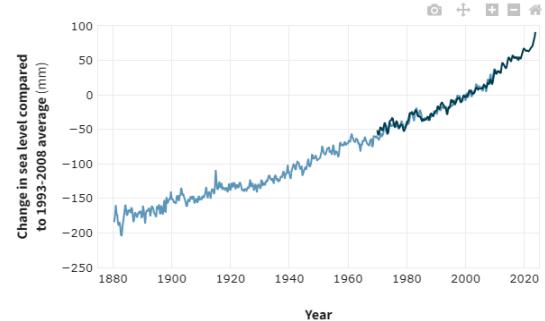
- Will likely ensure about **½-1 meter of sea level rise this century, or more** if other effects (accelerated melting, heating and melting acceleration, AMOC slowdown, etc.) also occur.
- At sustained warming levels **between 2 C and 3 C, the Greenland and West Antarctic ice sheets will be lost almost completely and irreversibly** over multiple millennia, causing **several meters of sea level rise** (limited evidence)
- If 2°C becomes the new constant Earth temperature we **may be committing the planet to between 12–20 meters sea-level rise**, even if air temperatures later decrease. This is due to a warmer ocean that will hold heat longer than the atmosphere, plus a number of self-reinforcing feedback mechanisms, so that it takes much longer for ice sheets to regrow (tens of thousands of years) than lose their ice.
- Current **1-in-100 year extreme sea level events are projected to occur at least annually** in more than half of all tide gauge locations by 2100 under all considered scenarios (high confidence). By 2050, up to 1 billion people could be exposed to extreme sea level events that used to occur once a century and will now be occurring 20-30 times more frequently.
- Committing the planet to **extensive coastal loss and damage** well beyond limits of feasible adaptation.
- **2°C is far too high to prevent extensive sea ice loss at both poles, with severe feedbacks to global weather and climate.**
- The Arctic Ocean will be sea **ice-free in summer almost every year**; and for periods of up to four months (July–October).
- Open water in the Arctic for several months will absorb more heat from polar 24-hour sunlight conditions. **A warmer Arctic will increase coastal permafrost thaw – adding more carbon to the atmosphere** – and speed Greenland Ice Sheet melt and resulting **sea-level rise**.

IMPACTS of Global Warming at 2.0 °C

- In the Antarctic, **complete loss of sea ice every summer** seems plausible at 2°C if current trends continue, and would **almost certainly speed up loss from the Antarctic ice sheet and resulting sea-level rise**.
- Due to unavoidable sea level rise, **risks for coastal ecosystems, people, and infrastructure** will continue to increase beyond 2100 (high confidence). A 46 cm of sea level rise by 2100 (a 15% increase from 1.5 C) exposes 69 million people to disasters like **flooding in coastal areas**.



GLOBAL SEA LEVEL



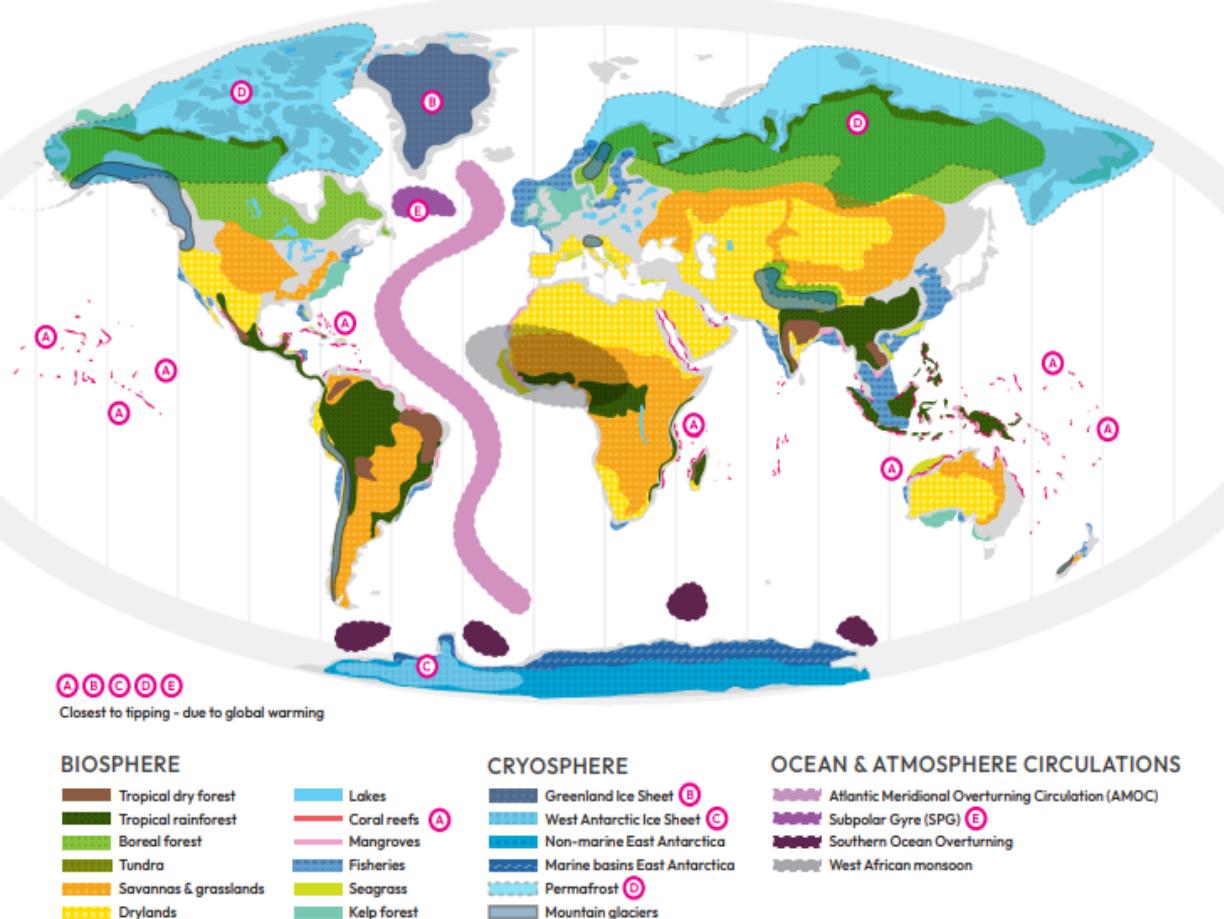
<https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level>

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6. TIPPING POINTS THE TRENDS

On Dec 6, 2023, a major study on Tipping Points by more than 200 climate scientists was published. The announcement is at: <https://www.nature.com/articles/d41586-023-03849-y>. The 500 page report, and its constituent sections and summaries, can be accessed at: <https://global-tipping-points.org/>. We covered a lot of this report in **CSSG-2.11, 12, 13, and 17**.

The chart below catalogs the 26 potential tipping points of most concern.



<https://global-tipping-points.org/>

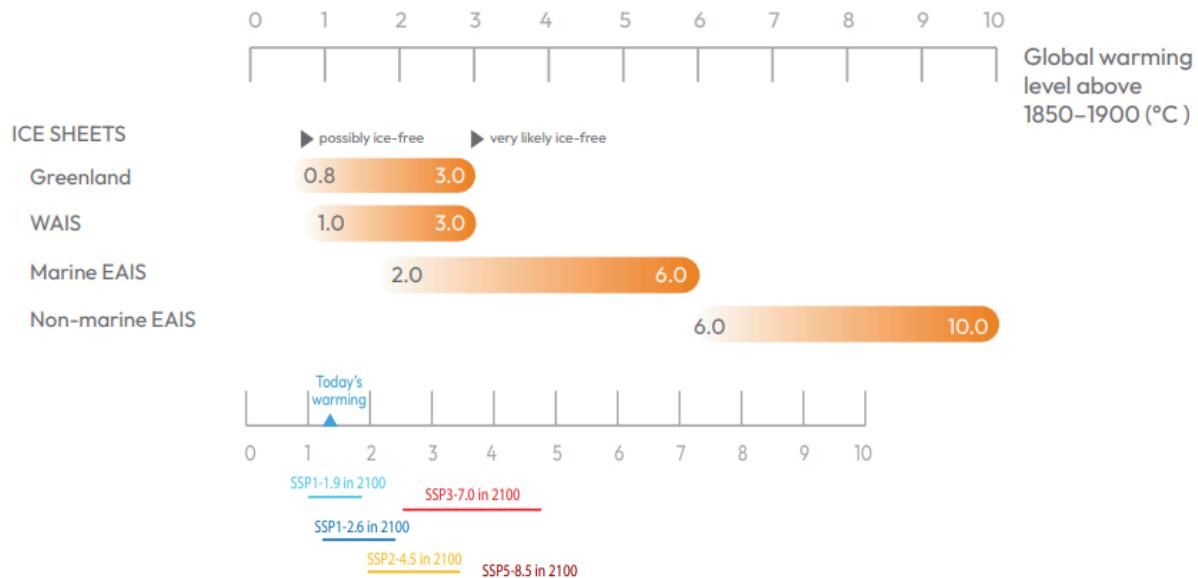
Materials Library at: <https://drive.google.com/drive/folders/100OYwNz92CbY-pC-aYEDrwJTxLj8JUZf?usp=sharing> maclankford@gmail.com

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Five of the 26 potential tipping points (A) - (E) were flagged as being **already at risk** of crossing tipping points at 1.5 C:

- warm-water coral reefs (A),
- Greenland (B) ice sheet [7m sea level rise potential over centuries to millennia]
- West Antarctic (C) ice sheets [3m],
- permafrost regions (D), and
- North Atlantic Subpolar Gyre circulation (E).

For the tipping points of the **ice sheets**, Greenland and West Antarctica have both entered the range of instability:



[The “SSP” bars immediately above reference IPCC scenarios varying from very aggressive action against global warming up to “business as usual” increases in emissions.]

IMPACTS of Global Warming at 2.0 °C

TIPPING POINTS

SPECIFIC Additional IMPACTS at 2.0 °C

- All of the Earth's frozen parts will experience irreversible damage at 2°C of global warming, with disastrous consequences for millions of people, societies, and nature. 2°C of global warming will trigger irreversible loss to Earth's ice sheets, mountain glaciers and snow, sea ice, permafrost, and polar oceans.

Between 2 degrees C (3.6 degrees F) and 3 degrees C (5.4 degrees F), for example, the **West Antarctic and Greenland ice sheets could melt almost completely and irreversibly** over many thousands of years, causing sea levels to rise by several meters.

- Coral Reefs would be 99% destroyed
- The AMOC moves into a higher risk for collapse with resulting climate devastation to northeast Europe and a meter sea level rise on the east coast of North America.



<https://www.pnas.org/doi/full/10.1073/pnas.2404766121>

<https://www.washingtonpost.com/climate-environment/2024/05/20/thwaites-glacier-melt-sea-level-rise/>

IMPACTS of Global Warming at 2.0 °C

Punchlines for our Situation at 2.0 °C

1. SURFACE TEMPERATURE and PRECIPITATION CHANGES

- 5x more heatwaves, more frequently combined with droughts. More than a third of the global population would be impacted in a five year period.
- Expanding regions of more precipitation and flooding and intense storms.
- Permafrost thawing will add to long-term global heating.

2. SOIL MOISTURE and FOOD PRODUCTION

- Most glaciers are melted/melting, with major downstream damages and dry-season impacts.
- Agricultural yields fall rapidly. Fishing is strongly threatened by extensive corrosive ocean acidification.
- 8% of the global population face severe water shortages.

3. HEAT-HUMIDITY RISKS TO HUMAN HEALTH

- **Human Displacements are a major societal variable**, with more than a third of the global population highly vulnerable to climate change - including water stress, heat stress, nutrition-related diseases and undernourishment, and desertification.

IMPACTS of Global Warming at 2.0 °C

4. SPECIES EXTINCTIONS

- 18% of the 30,652 species assessed likely face a very high risk of extinction.
- Coral reefs are essentially wiped out.

5. SEA LEVELS

- Over $\frac{1}{2}$ meter of sea level rise, exposing over 50 million persons to coastal flooding, would occur this century. By 2050, up to 1 billion people could be exposed to extreme sea level events that used to occur once a century and will now be occurring 20-30 times more frequently.
- Unless the warming is actually reversed, over millennia this heating level would deliver 12-20 meters of sea level rise.

6. TIPPING POINTS

- Accelerated, irreversible melting of Greenland and West Antarctica ice sheets may have started, and can ultimately raise sea levels by over 6 meters. Near to 2 meters is possible this century.
- Other tipping points with dramatic climatic impacts, like collapse of the Atlantic Meridional Overturning Circulation (AMOC), thawing of permafrost regions, and loss of the Amazon rainforest, are (at 1.5 C) showing early warning signs of accelerating change.

IMPACTS of Global Warming at 2.0 °C



Figure 1.1.1: Illustration of the Earth system, showing the different 'spheres'.

IMPACTS of Global Warming at 2.0 °C

GOOD NEWS CORNER



Small island nations secure major climate ruling

EHN Curators

Island nations in the Pacific, Caribbean, and West Indies have won a landmark international legal victory, pressuring large governments to reduce carbon emissions.

<https://www.dailyclimate.org/small-island-nations-secure-major-climate-ruling-2668345237.html>

Global Tipping Points

ONE POSITIVE TIPPING POINT CAN TRIGGER OTHERS, CREATING A DOMINO EFFECT OF CHANGE For example, as electric vehicles pass a positive tipping point towards becoming a dominant form of transport, this reduces the costs of battery technology. Lower-cost batteries in turn provide essential storage capacity to reinforce the positive tipping point to renewable power, which can trigger another tipping point in producing green ammonia for fertilisers, shipping, and so on.

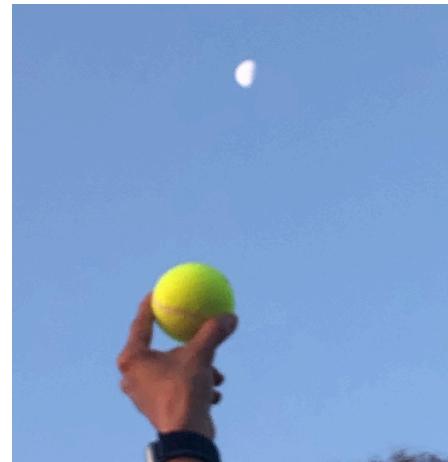
TRIGGERING POSITIVE TIPPING POINTS REQUIRES COORDINATED ACTION THAT CONSIDERS EQUITY AND JUSTICE Many areas of society have the potential to be 'tipped', including politics, social norms and mindsets. But these opportunities are not realised on their own. Concerted and coordinated action is usually needed to create the enabling conditions for triggering positive tipping points. Once near a tipping point, it may even be triggered by relatively small groups with targeted action. Appropriate governance can enable this process and is required to equitably manage its knock-on effects, so that all parts of society can engage with and benefit from tipping point opportunities.

<https://global-tipping-points.org/>

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Rosilis Cuevas

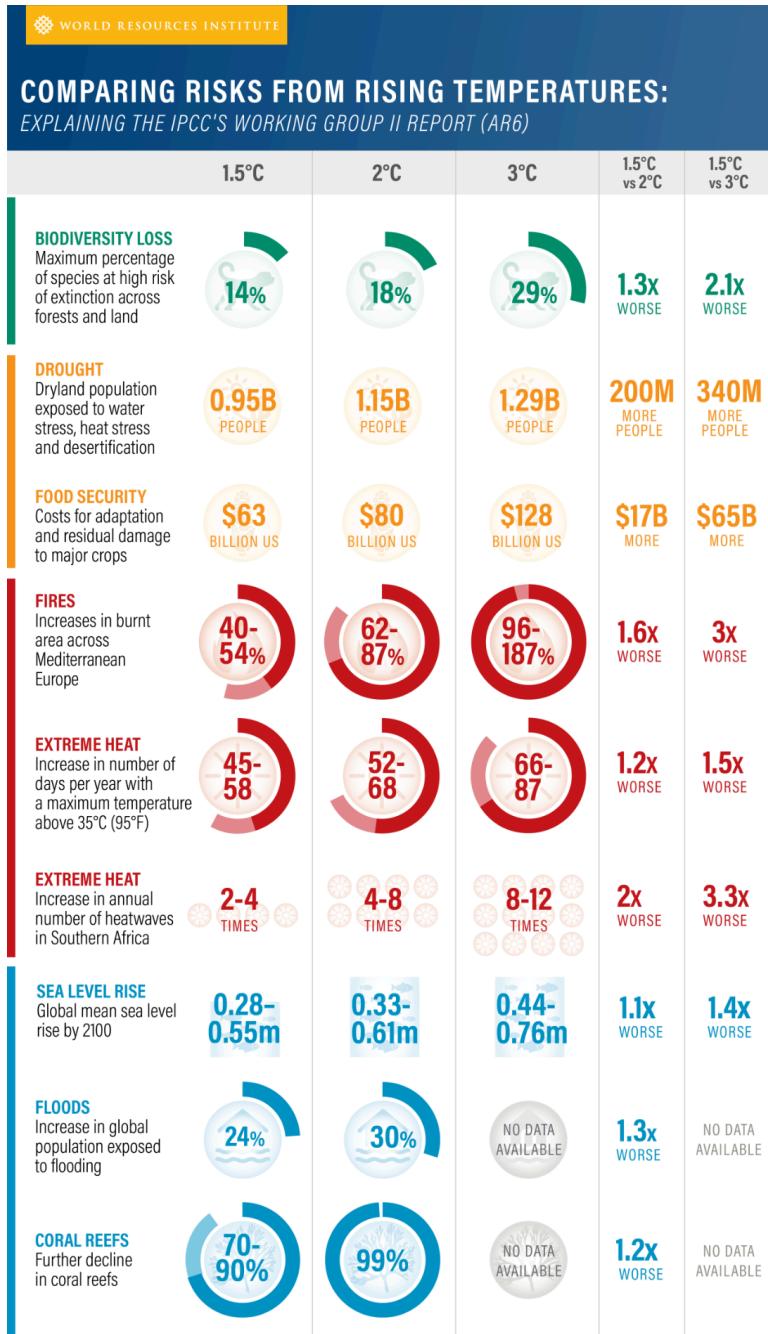
Ever Ready to RISK IT ALL for **SCIENCE !**



IMPACTS of Global Warming at 2.0 °C



IMPACTS of Global Warming at 2.0 °C



Note: For climate risks with projected ranges, we used the midpoint of the ranges to compare risks at different temperature thresholds. Sea level rise projections correspond to SSP1-1.9, SSP1-2.6, SSP2-4.5, which are roughly approximate to global warming of 1.5°C, 2°C, and 3°C, respectively. Source: IPCC AR6.

IMPACTS of Global Warming at 2.0 °C

Approximate “Cheat Sheet”:

1 meter → 3 feet **1 degree Celsius (°C)** → 2 degree Fahrenheit (°F)

ppm = parts per million **CO₂** = Carbon Dioxide

1 tonne = 1000 kilograms = 2205 pounds **1 gigatonne (1 Gt)** = 1 billion tonnes

1 trillion tonnes (1Tt) = 1000 gigatons