Likely 21st Century Impacts of our Current Fossil Fuel Emissions Trajectory

December 20, 2024 Update
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For the Climate Science Study Group

Introduction

There has been a huge amount of research into both the **TIMING** of global warming at various fossil fuels emission levels above pre-industrial times, such as 1.5 ^{0}C, 2 ^{0}C (2.7 ^{0}F, 3.6 ^{0}F), etc., and likely **IMPACTS** which may occur at those warming levels, and this research continues worldwide. The purpose of this present study is to home in on the largest scale impacts, which will likely be the most visible for governments and their constituents. It appears likely that only when these large scale impacts occur will critical international cooperation be stimulated. The question is: will it be too late to undo the damage?

Most of the information provided here is from the latest publications of the Intergovernmental Panel on Climate Change (IPCC). Other information comes from more recent research. All sources are cited and linked at the end.

Summary conclusions drawn from and framing these scientific materials are mine. [Sections directly keyed to the 2-3 ^{0}C warming levels projected for the 2040 - 2070 ± period are highlighted in Yellow]. **This is my most significant takeaway:**

At our current
fossil fuel emissions trajectory,
we'll likely have

Global Societal Disruption

by 2040 - 2070

And the disruption is already starting…

To change this, we would have to change our path.

To set the stage properly: We have a Problem and we can measure it.

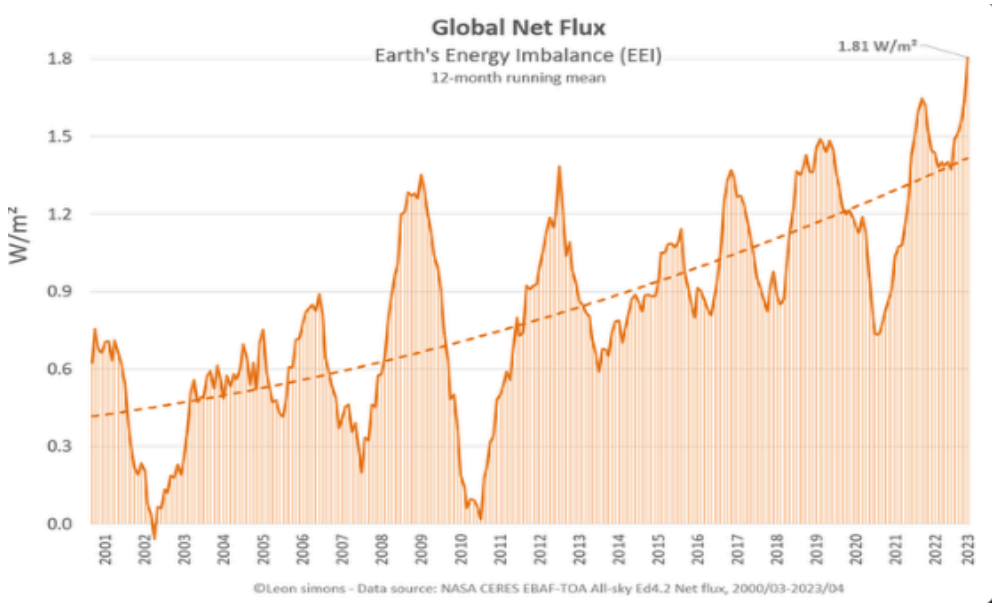
The Earth's Energy Imbalance (EEI) can now be directly measured from space. It tells us that the Planet is receiving and holding more energy from the Sun than we can radiate back out into space, so it is warming up. In addition, the Earth is holding more and more energy over time.

This means the warming is accelerating (and NOT reducing).

This is the Earth's Energy Imbalance

(W/m^2 averaged over the Earth's surface)

It is increasing over time ⇒ Accelerated Warming [a]



This graph records estimates of net top-of-the-atmosphere annual energy flux from the CERES satellite. Credit: NASA

The IPCC has made it clear: Human activities, principally through emissions of greenhouse gases [via burning of fossil fuels], have unequivocally caused global warming.[b] Measuring the Earth Energy Imbalance documents <u>how</u> the warming occurs.

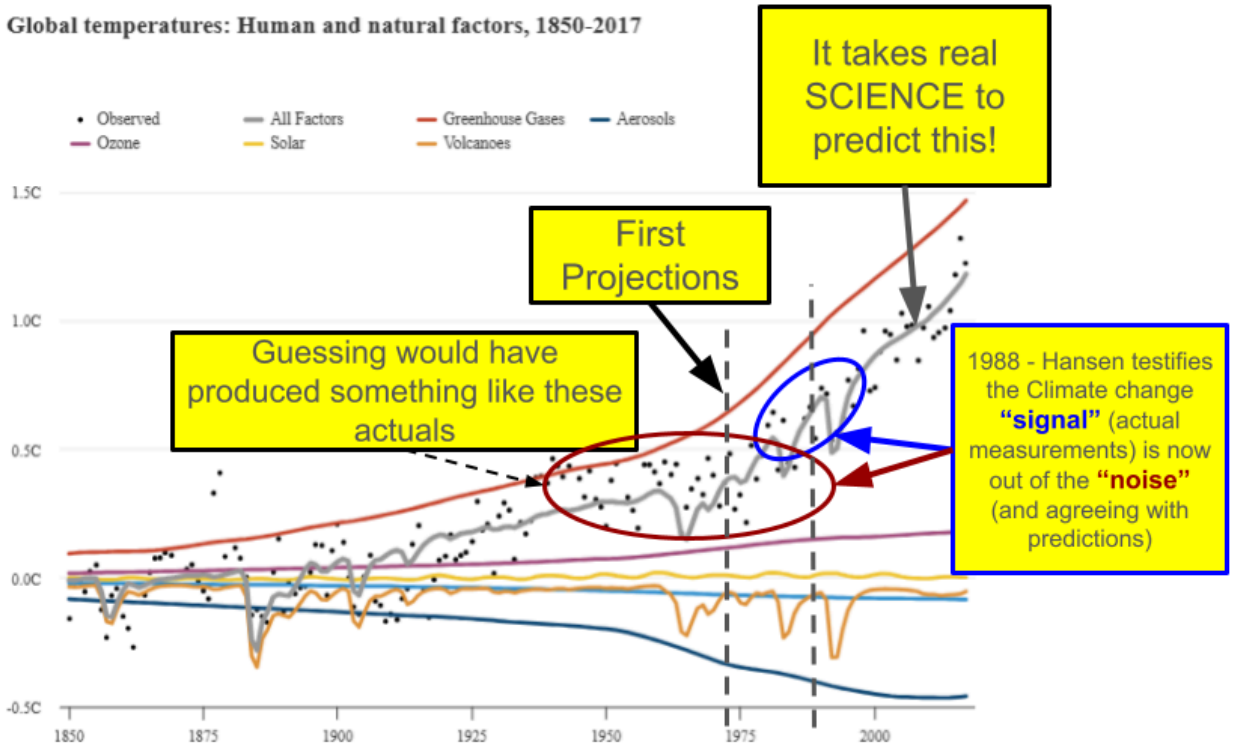
The implications of this graph are severe: our planetary use of fossil fuels and other human behaviors are causing the increased and increasing warming. This heating of the planet is causing climates, weather, sea levels, and habitability to change worldwide.

This Study assumes that we will continue to cause this warming with our current behaviors. Notwithstanding much talk about reducing fossil fuel pollution, it is in fact not happening - 2023 was yet another record emissions year. In fact, the planet is heating up even more than expected by the IPCC.

Confirmation that we have a Problem

- Past Predictions (since 1973) have been very much in line how warming has unfolded

The Data that Proved that the Scientists knew what they were talking about



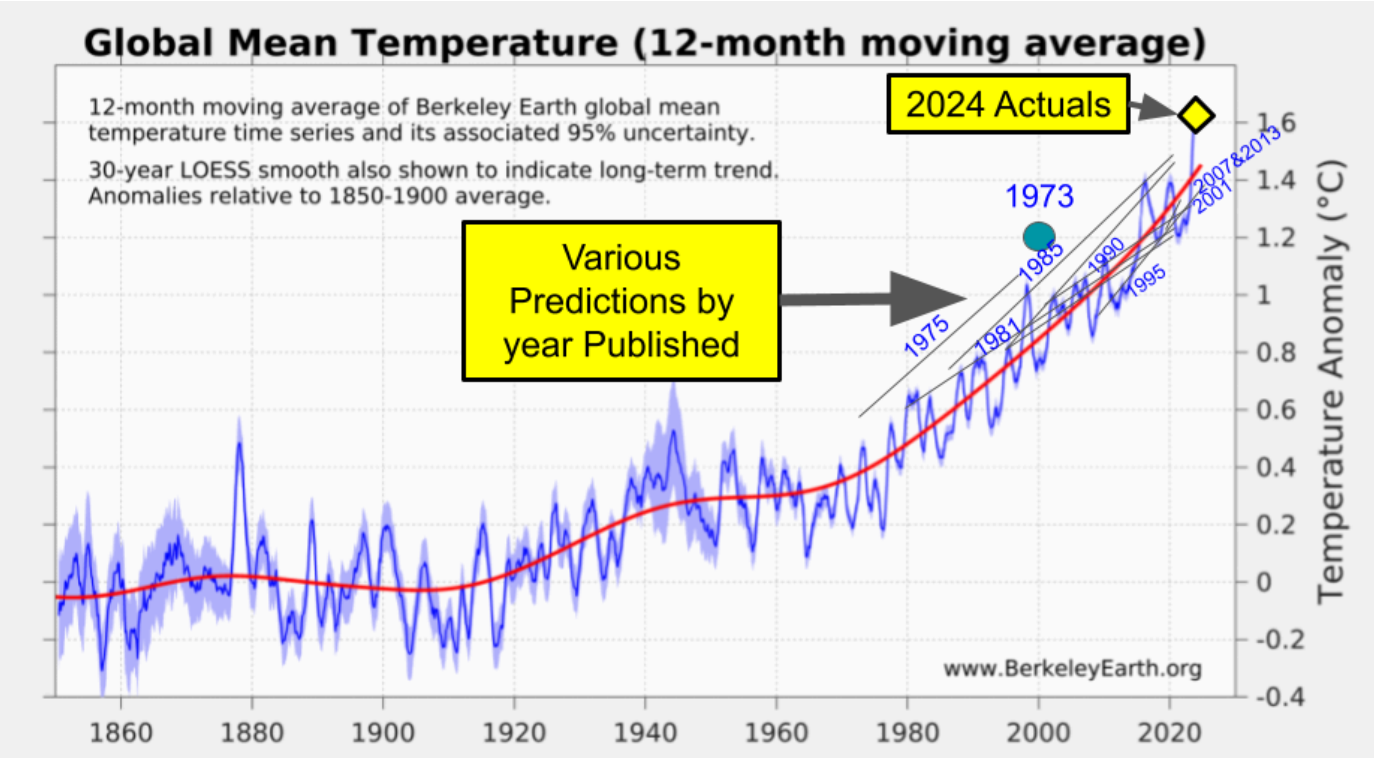
The story of these scientific predictions is amazing to me. Notice the BLACK DOTS in the graphic above, which show the average global temperature measured for each year. That is the "Actual" data available (the gray line is a running average of the black dots, resulting from all factors). Climate scientists by 1933 had actually started sorting out how the individual factors (all the other lines) should be adding up to give the gray line of actuals. The period from 1950 - 1980 seemed stable and stimulated a discussion, for a few years, of global cooling from ice age factors or from aerosols. The conclusion was that the aerosol (particulate) pollution was hiding the warming. So, the "Signal" was still not emerging from the "Noise". By 1988, predictions were being validated by the data (the **SIGNAL** was emerging from the **NOISE**) and the world conversation clarified.

The Predictions that Proved that the Scientists knew what they were talking about

Climate models published since 1973 have generally been quite skillful in projecting future warming. While some were too low and some too high, they all show outcomes reasonably close to what has actually occurred, especially when discrepancies between predicted and actual CO2 concentrations and other climate forcings are taken into account.

Models are far from perfect and will continue to be improved over time. They also show a fairly large range of future warming that cannot easily be narrowed using just the changes in climate that we have observed.

Nevertheless, the close match between projected and observed warming since 1970 suggests that estimates of future warming may prove similarly accurate.

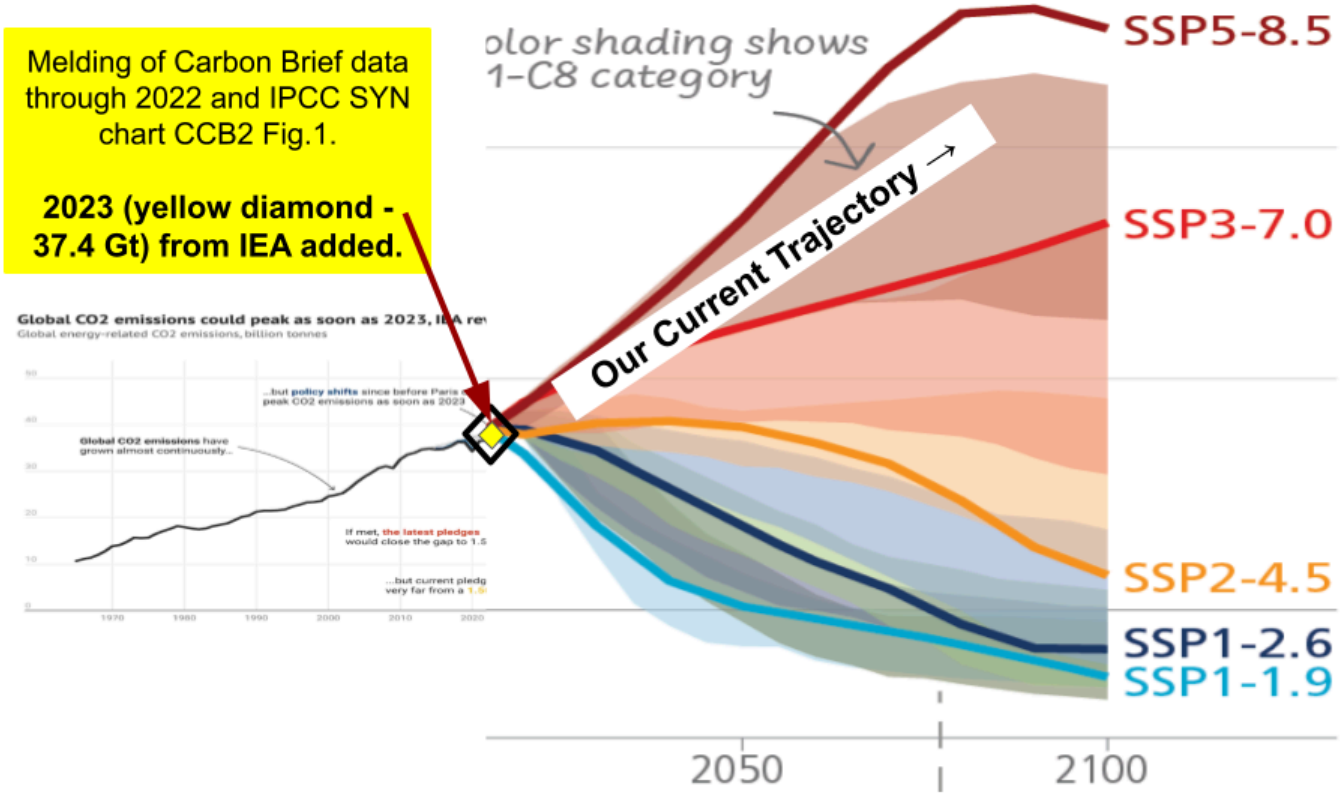


Analysis: How well have climate models projected global warming? - Carbon Brief 2017

- <u>Actual Emissions</u> portend accelerated Warming

The first chart below shows our CO_2 emissions trajectory (i.e., our actual behaviors) in the context of <u>assumed</u> emissions for the various IPCC cases (SSP5-8.5 is their "Very High" case). The Yellow Diamond indicates that 2023 set a new record, however the rate of increase may be lessening. It is too early from this single metric to discern our trajectory clearly. All are similar at this point. **But our behaviors are NOT turning around.**[q]

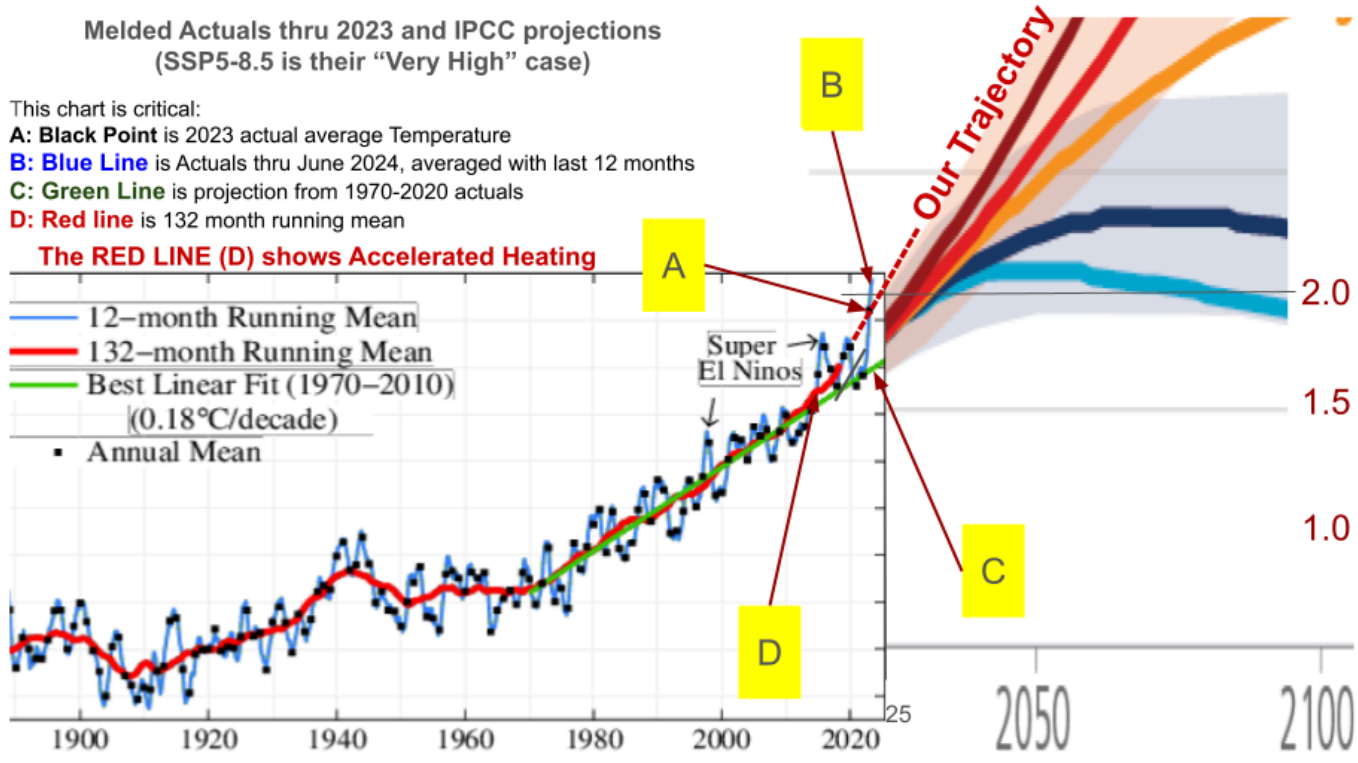
Here's how our emissions trajectory looks in relation to the high emission cases (SSP5-8.5 and SSP3-7.0) used by the IPCC:



- The planet is <u>actually warming faster</u> than Projected

More telling than simply tracking emissions vs. <u>projections</u> on the planet's response, is a comparison of how the planet <u>is actually responding (i.e., warming up - the planet's behavior) vs. expectations</u>. This is more directly tied to the Earth's Energy Imbalance than indirect assumptions on how emissions would hold heat. Below is a direct confirmation that the planet is heating and that it is heating faster even than IPCC had projected. The long-term trajectory **(the RED LINE D)** is diverging from the past (C).

NOTE THE PROXIMITY of A&B TO 1.5 ^{0}C (2.7 ^{0}F) warming above the pre-industrial average. This was the goal of the Paris Agreement in 2015 and it appears likely that this goal has been breached. The planet is heating even faster than the IPCC projected for a case between SSP5-8.5 and SSP3-7.0, where our trajectory shows up in the previous chart.



- The Most Recent Trends are alarming

On October 8, 2024, a group of top climate scientists updated the 2024 state of the climate report: Perilous times on planet Earth | BioScience | Oxford Academic as part of their series of concise annual updates on the state of the climate. Your attention to the full report is recommended; some key information and findings are set forth on this page and are consistent with other parts of this study.

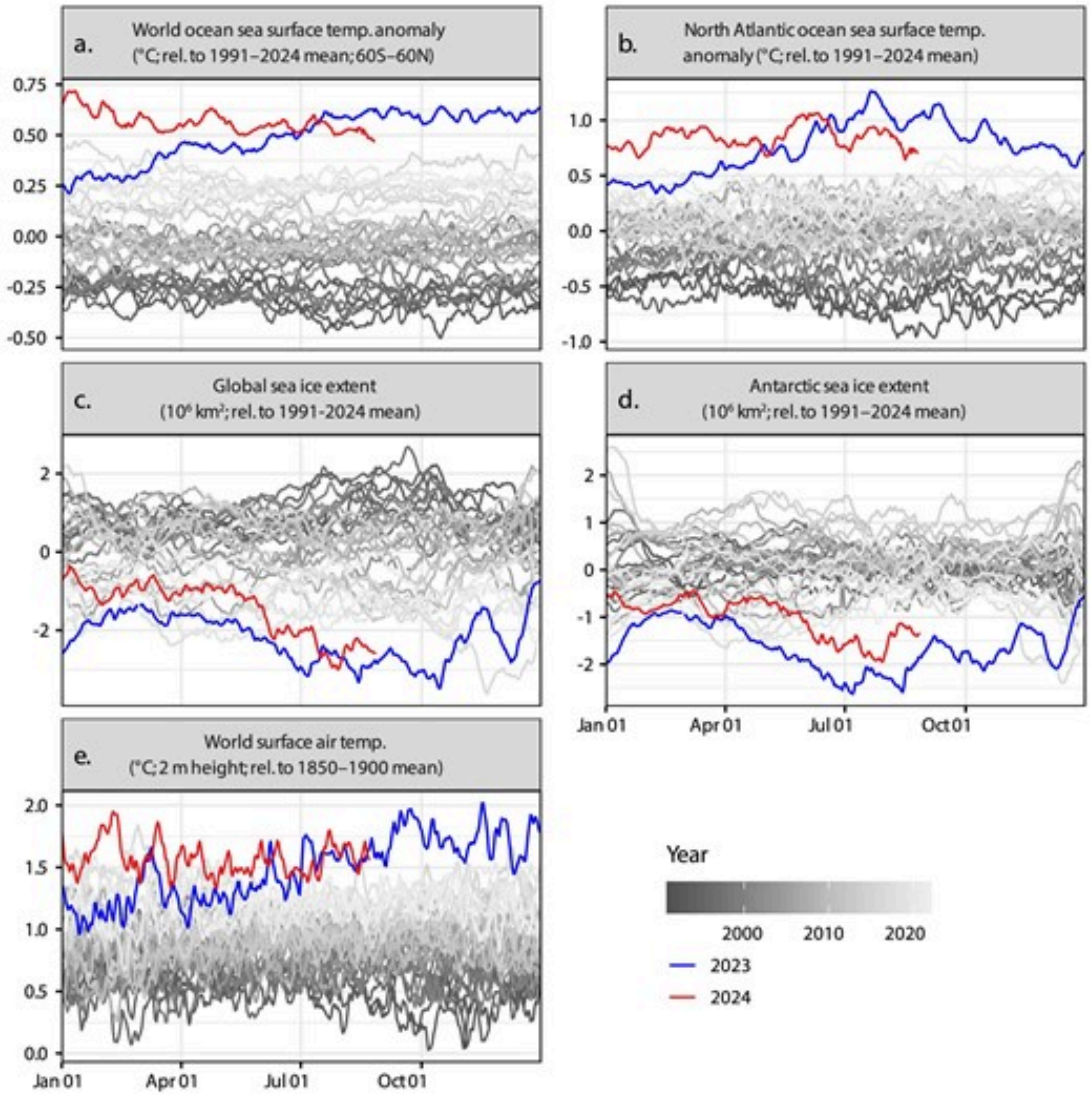


Figure 1.Unusual climate anomalies in 2023 and 2024. Ocean temperatures (a, b) are presently far outside their historical ranges. These anomalies reflect the combined effect of long-term climate change and short-term variability. Each line corresponds to a different year, with darker gray representing earlier years, light gray, the most recent years.

Surface temperature is at a record high, and 2024 is expected to be one of the hottest years ever recorded. Each 0.1°C of global warming places an extra 100 million people (or more) into unprecedented hot average temperatures. On our current trajectory, future years will almost certainly be even hotter, because our climate continues to shift away from conditions associated with human thriving for much of Earth's population.

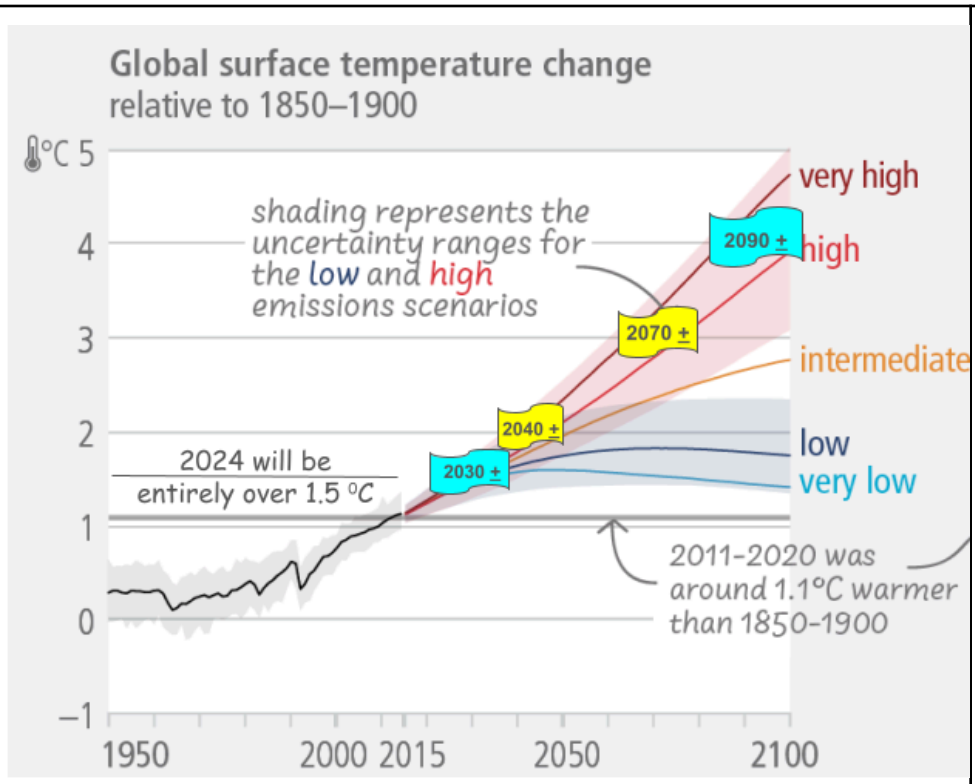
Climate change has already displaced millions of people, and has the potential to displace hundreds of millions or even billions more, leading to greater geopolitical instability. By the end of the century, roughly one-third of people worldwide could be outside the human climate niche, facing increased risk of illness and early death, famine, and a host of other adverse outcomes.

What might be the TIMING of WARMING?

There are a lot of factors which will come into play as the actual warming of the planet unfolds. Scientists have studied how the planet has responded to changes in conditions as it moved from ice ages to warmth, the current conditions of the oceans, cloud responses, the physical effects of each greenhouse gas, the reflectivity of man-emitted aerosols which we are now cleaning up, etc.

While this leaves a degree of uncertainty as to what exact temperature change an assumed emissions trajectory will cause, it is reasonable to use the following IPCC chart [c] to get a best-but-rough-estimate of TIMING.

Because we are not reducing our use of fossil fuels so far, and seem unlikely to achieve it anytime soon, it would be **imprudent to close our eyes to the likelihood of continued "Very High" to "High" emissions cases**. I use these curves to estimate when we might reach benchmark temperatures.



Rough-but Best-Estimate TIMING of Benchmark Temperature Changes since pre-industrial times

2030 ± 1.5 °C = 2.7 °F
(may be there now)

2040 ± 2.0 °C = 3.6 °F
2070 ± 3.0 °C = 5.4 °F

2090 ± 4.0 °C = 7.2 °F
2120 ± 5.0 °C = 9.0 °F

Note that yellow highlighting will be used to focus on these conditions and period of time

Conversations and debates on timing continue in the scientific community, even with sharp disagreements on important details at times. For example, Hansen, et al. recently stimulated a lot of discussion around the impacts of aerosols, resulting albedo (reflectivity) changes, and improved understanding of paleo (prehistoric) circumstances.[d] Notwithstanding the controversies involved, even such revised timing estimates fit into this general picture.

What might be the IMPACTS of WARMING?

A thorough review of the IPCC 2023 Synthesis Report is so important, but tends to boggle the mind with details. The number of scientific studies on topics from food production to hurricanes and from coral reefs to a region in East Africa to global impacts provides so much information that it is near impossible to get a sense of the level of dangers (or not) we may face.

There are, however, projected changes which indeed have global physical and societal implications and which should make one sit up and pay attention.

To get right down to it: given the timing of various temperatures if we keep on our current path, we seem very likely to endure major worldwide disruptions in the next 2-5 decades. These will not just be disruptions of various ecosystems, but also of day-to-day life and of most, if not all, social structures.

The basis for that assertion is documented in this Study. The big picture that has come together, supported directly by the referenced IPCC materials, is a world of massive human relocations caused by global climate changes, topped off by ongoing challenges with enormously intensified and erratic weather.

Here is presented the world which we appear to be constructing:

CONDITIONS WHICH WOULD FORCE GLOBAL MIGRATIONS by 2040 - 2070:

1. **Rising Temperatures and Intensified Precipitation**
2. **Species Extinctions and Migrations**
3. **Expanding regions risking Mortality for Humans**
4. **Major shifts of the human temperature niche by 2070**

CONDITIONS WHICH WOULD CAUSE CONTINUOUSLY DISRUPTED LIVING, even in “Human Niche” Regions:

5. **Increasingly Erratic and Intense Weather**
6. **Rising Sea Levels**
7. **Tipping Points and Compounded Impacts**

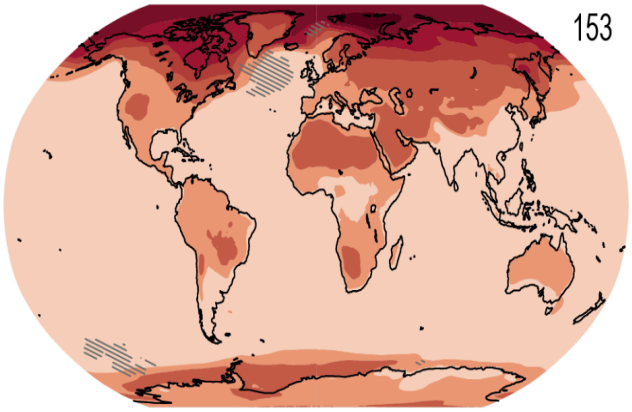
Let’s take a look at these specific projected **IMPACTS**. They are just the tip of the iceberg in the materials brought together by IPCC and others, but were selected because they emphasize major global trends and effects. **NOTICE THE WORSENING CONDITIONS AS DECADES PASS.**

CONDITIONS WHICH WOULD FORCE GLOBAL MIGRATIONS

1a: Average Temperatures (are already rising)

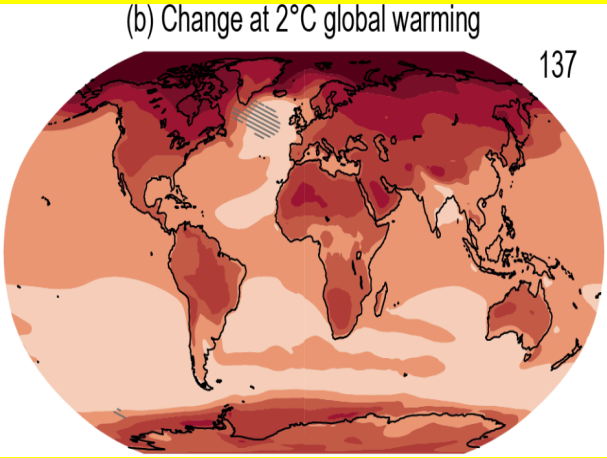
[Note that, locally, the annual **maximum temperatures** experienced can be much higher than these averages shown - **typically increasing by up to 8 ^{0}C in the 4 ^{0}C global warming scenario**.] [7]

(a) Change at 1.5°C global warming



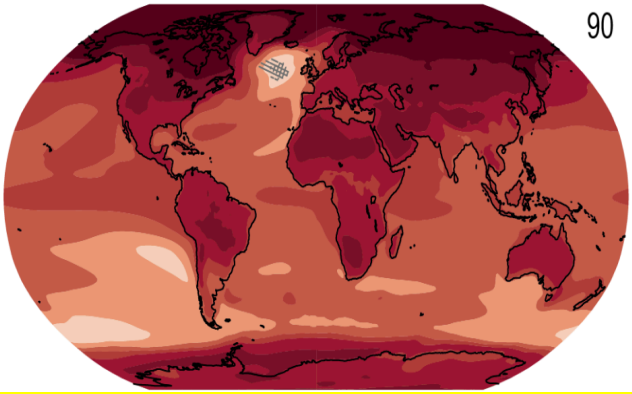
2030 + Hot extremes including heat waves have already become more frequent and intense over most land regions. Regional increases in temperature, aridity, and drought have increased frequency and intensity of fire [f]

(b) Change at 2°C global warming



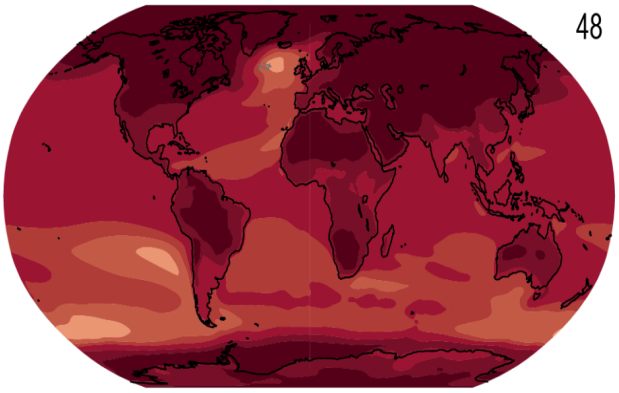
2040 + for this warming, with associated precipitation changes, global land area burned by wildfires is projected to increase by 35% [f]

(c) Change at 3°C global warming

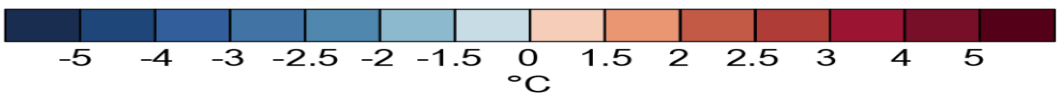


2070 + Equatorial regions are less habitable, while the same temp increase can make polar regions more comfortable

(d) Change at 4°C global warming



2090 +

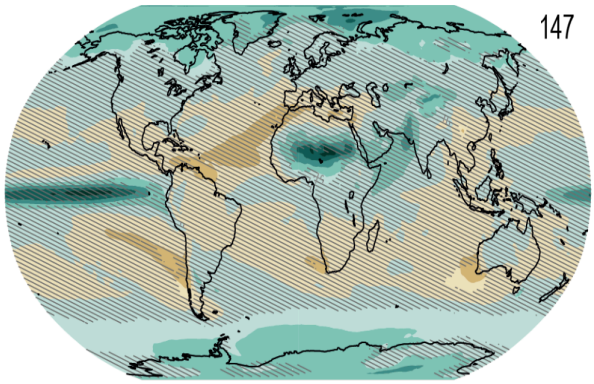


1b: Intensifying Precipitation (has already started)

At the same time as the above major changes in temperature are occurring, rainfall is also expected to modify in **intensity and total precipitation.** These changes can be strongly increasing or strongly decreasing total rainfall. [8] Note also regions developing extreme drought such as the Mediterranean.

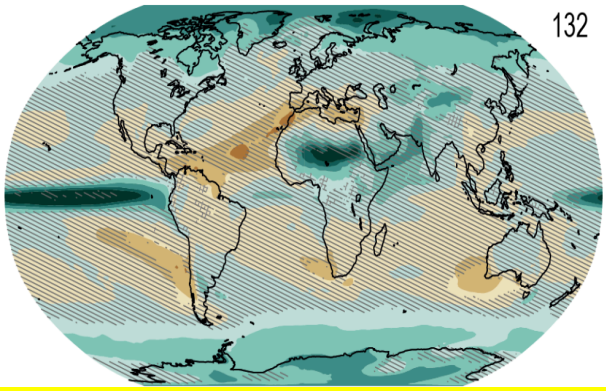
Rising temperatures and increased precipitation go together. A 1 ^{0}C (5.4 ^{0}F) rise in temperature allows air to hold 7% more moisture. This wetter, warmer air rises, it rises faster than previously, cools rapidly, and drops more water than before. So rains are more intense and drop more water than in cooler conditions. *[Side note: Sahara moisture is a strong increase from a very small initial value.]*

(a) Change at 1.5°C global warming



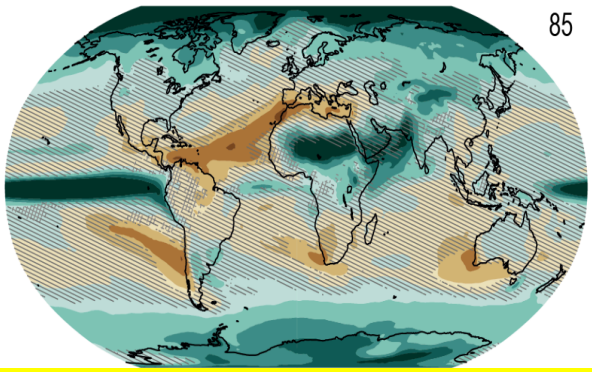
2030 + Already nearly 50% of coastal wetlands have been lost from combined pressures, including sea level rise, warming, and extreme climate events [f]

(b) Change at 2°C global warming



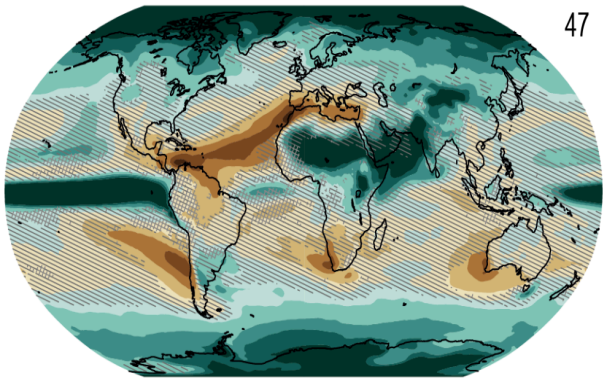
2040 + direct flood damages are up to 2x those at 1.5 C.[r] East Asia, Amazon, and Mediterranean drying.

(c) Change at 3°C global warming

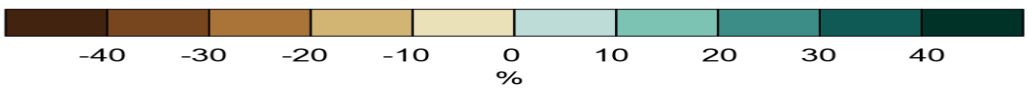


2070+direct flood damages are up to 3.9x those at 1.5 C.[r]

(d) Change at 4°C global warming



2090 + Severe droughts in Mediterranean

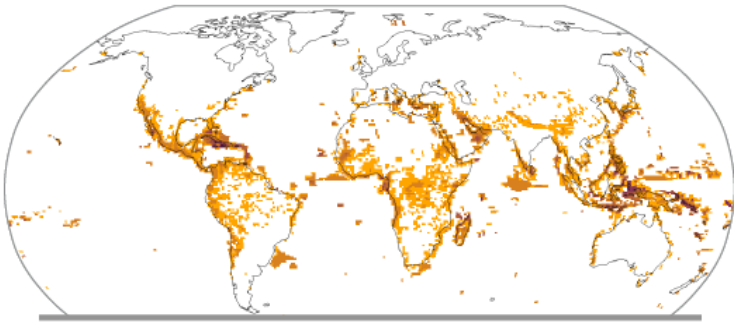


2. Species Extinctions and Migrations (have started)

There are already obvious changes in the species we encounter and read about. The IPCC covers many relevant issues, including habitat losses in biodiversity hotspots. The charts here depict the projected percentage of species which would be exposed to temperature conditions above the estimated historical (1850-2005) maximum mean annual temperature experienced by each species, assuming no species relocation. Includes 30,652 species of birds, mammals, reptiles, amphibians, marine fish, benthic marine invertebrates, krill, cephalopods, corals, and seagrasses.

The obvious implications are devastating disruptions in habitats as we go forward, particularly towards the equatorial regions. This is consistent with the threats to humans in the next section.

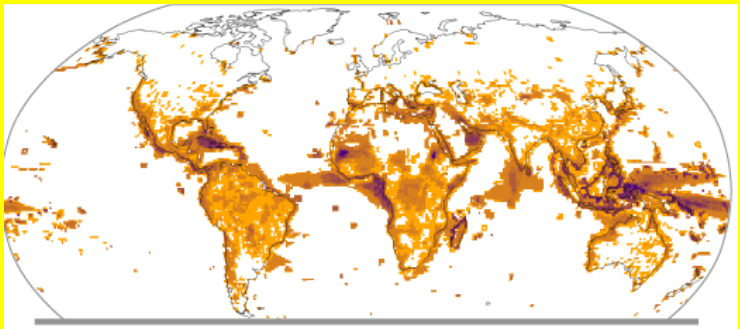
Percentage of **species exposed** to dangerous climatic conditions [e]



1.5°C

2030 ± **3-14%** of the land and forest species assessed likely face a very high risk of extinction. [e]

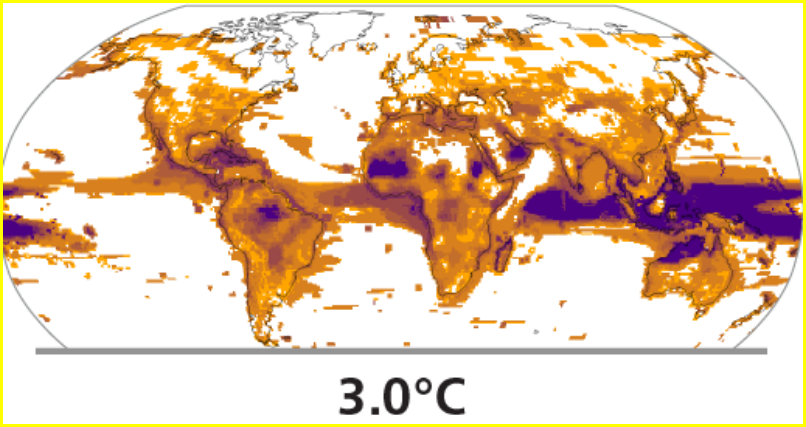
Climate change has caused mass mortality events of plants and animals. **½-⅔ of these species have shifted range to higher latitudes and ⅔ have shifted to earlier spring events.**[f]



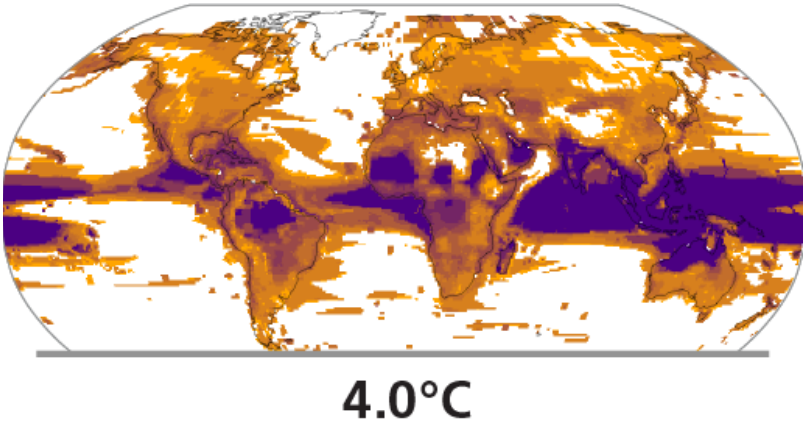
2.0°C

2040 ± Up to **18%** of the land and forest species assessed likely face a very high risk of extinction.[e]

Percentage of **species exposed** to dangerous climatic conditions [e]



2070 ± Up to **29%** of the land and forest species assessed likely face a very high risk of extinction.[e]



2090 ± Up to **39%** of the land and forest species assessed likely face a very high risk of extinction.[e] local extinctions af about 50% of tropical marine species.[r]

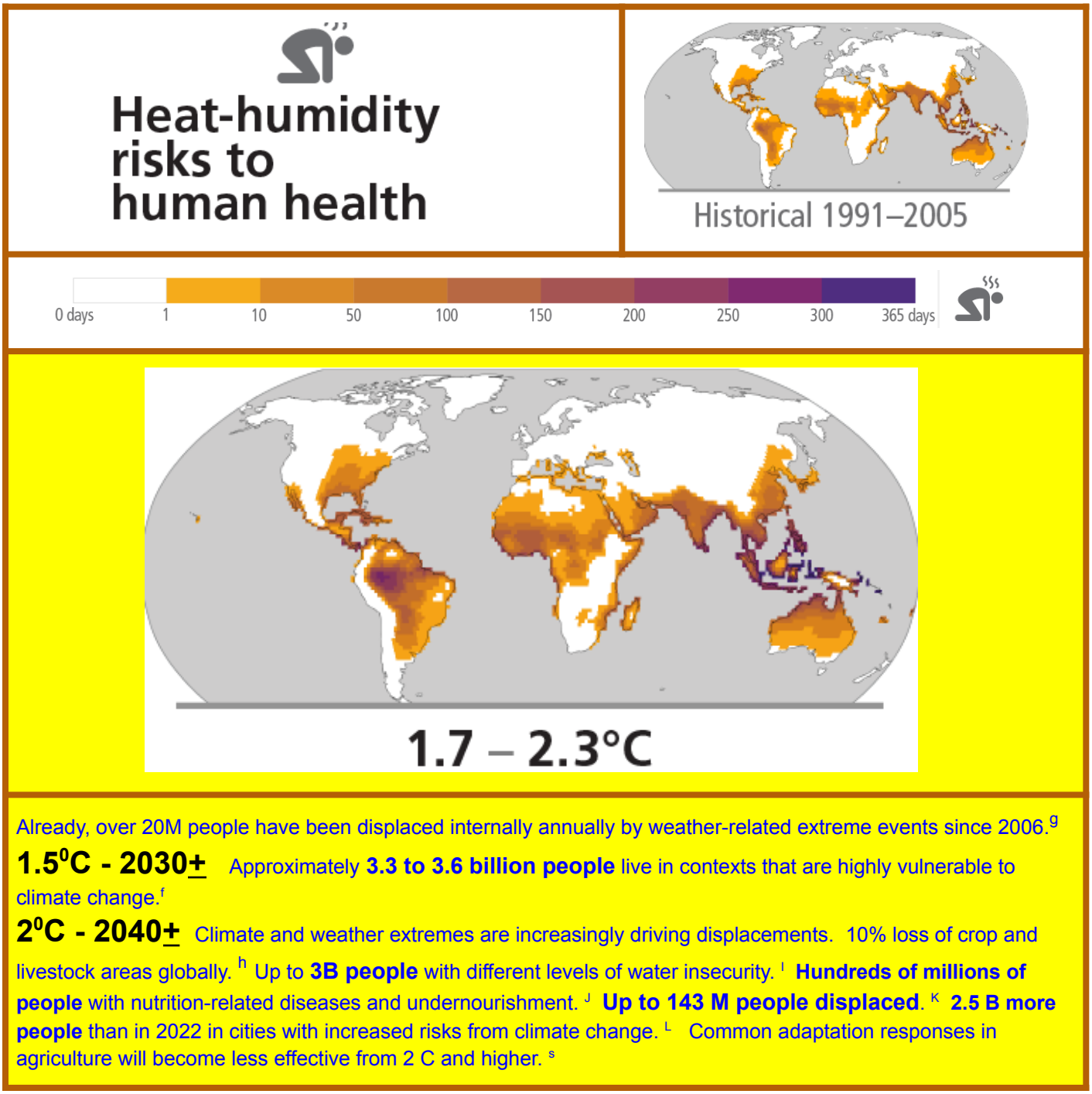
At 5 °C **2120 ±** Up to **48%** of the land and forest species assessed likely face a very high risk of extinction.[e]

This picture of what is likely to happen to non-human species is devastating.
Already in 2024 we are experiencing mass extinctions in local areas and large movements in latitude to deal with the increasing heat.

Even if it is assumed that ALL of the species were able to relocate (they certainly could not), the conditions for any species and food production near the equator could be hugely jeopardized in a very few decades.

3. Expanding regions with risk of Mortality to Humans from heat, humidity, disease, malnutrition

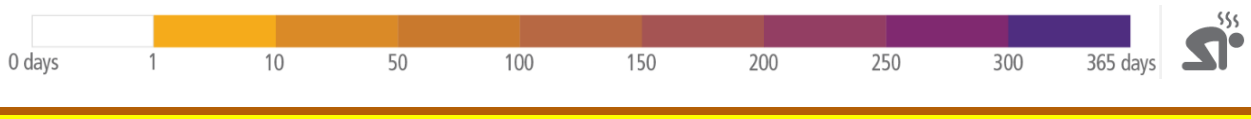
These temperature increases, combined with humidity, will have direct effects on humans. More areas will become less habitable as **the number of dangerous days in the year increase**, posing a risk of mortality increase. Add to that related increasing diseases and malnourishment.

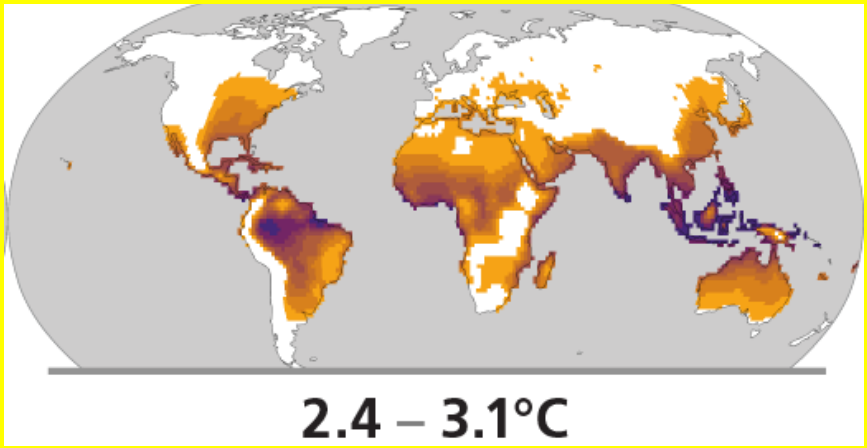


Already, over 20M people have been displaced internally annually by weather-related extreme events since 2006.[g]

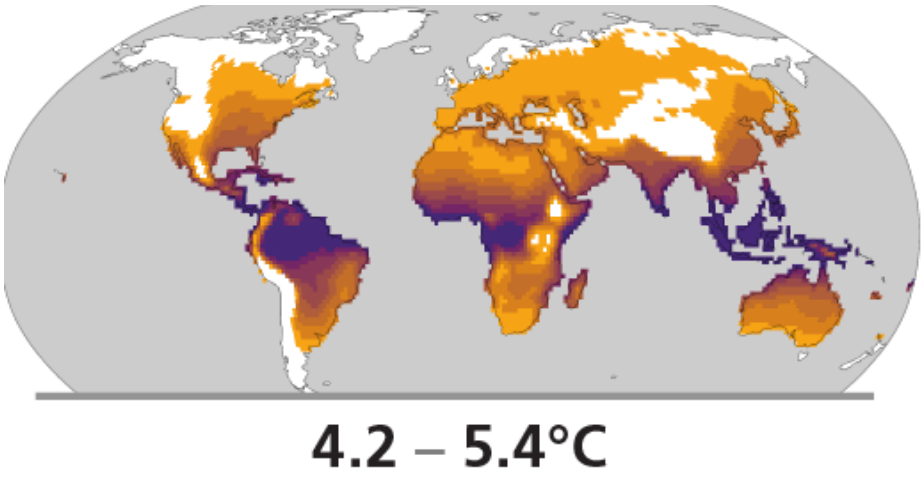
1.5^{0}C - 2030+ Approximately **3.3 to 3.6 billion people** live in contexts that are highly vulnerable to climate change.[f]

2^{0}C - 2040+ Climate and weather extremes are increasingly driving displacements. 10% loss of crop and livestock areas globally.[h] Up to **3B people** with different levels of water insecurity.[I] **Hundreds of millions of people** with nutrition-related diseases and undernourishment.[J] **Up to 143 M people displaced**.[K] **2.5 B more people** than in 2022 in cities with increased risks from climate change.[L] Common adaptation responses in agriculture will become less effective from 2 C and higher.[s]





3^{0}C - 2070± Adverse impacts on all food sectors becomes prevalent [j] **2.25 B more people** at risk from dengue.[m] Globally, adaptation options related to agroforestry and forestry have a sharp decline in effectiveness at 3 C with a substantial increase in residual risk. [S] Notice the wide equatorial swath with >⅓ - ½ of the year impossible to be outside.



4 ^{0}C - 2100 ± **4 B people** with different levels of water insecurity. [i] 30% loss of crop and livestock areas globally. [H]

Projected regional impacts utilize a global threshold beyond which daily mean surface air temperature and relative humidity may induce hyperthermia that poses a risk of mortality. The duration and intensity of heatwaves are not presented here. Heat related health outcomes vary by location and are highly moderated by socio-economic, occupational and other non-climatic determinants of individual health and socio-economic vulnerability.

The concern is obvious: **more and more regions may become uninhabitable for Humans**.

4. Major shifts of the human temperature niche by 2070

Similar to the human mortality and species extinction information above, a separate study focused on the projected geographical shift of the "human temperature niche" by 2070. For millennia, human populations have resided in the same narrow part of the climatic envelope available on the globe, characterized by a major mode around 11°C to 15°C (52-59 ^{0}F) mean annual temperature.

This niche presentation is, of course, just another way of noticing that major human migrations are almost inevitable given our current path.

Projected geographical shift of the human temperature niche by 2070 [n]

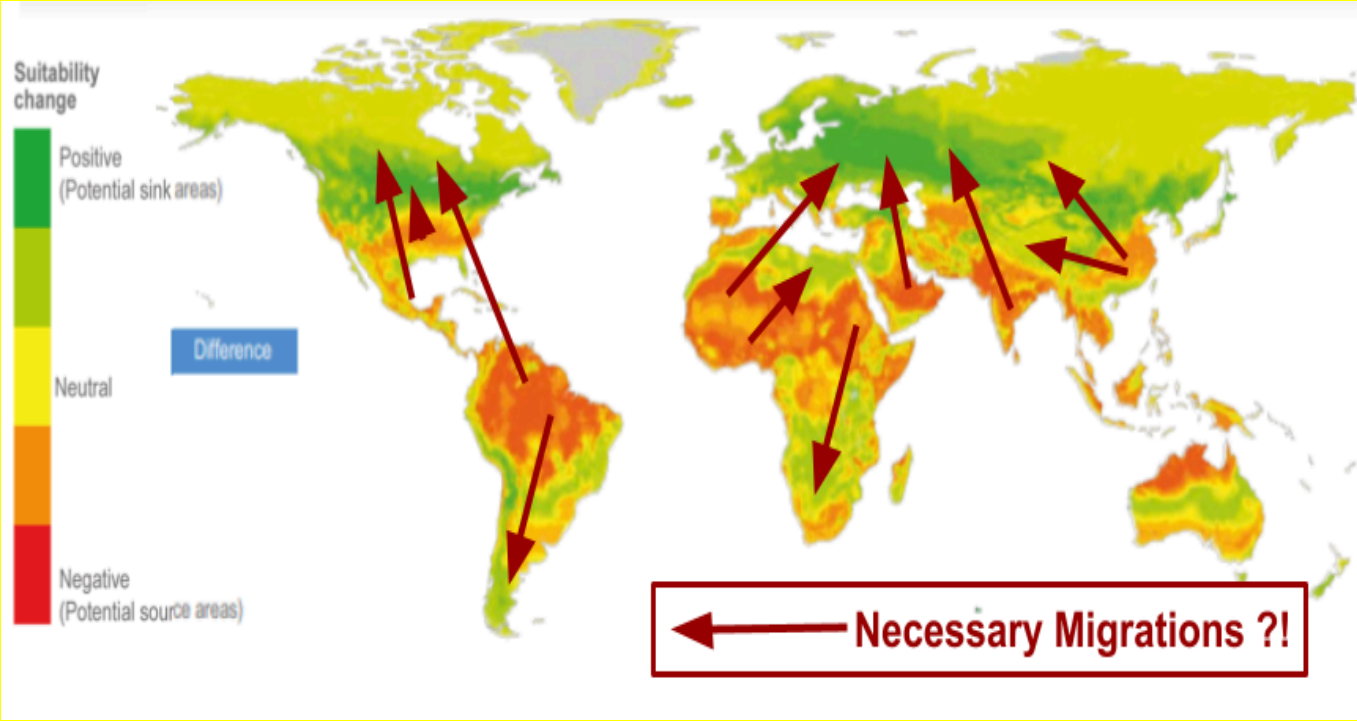


Figure AI.28 | . Geographical position of the human temperature niche projected on the current situation and the Representative Concentration Pathway RCP8.5 **projected 2070 climate** if humans were to be relocated in a way that would maintain this historically stable distribution with respect to temperature.

1.5^{0}C - 2025 ± Approximately 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change (high confidence)	**2^{0}C - 2040 ±** Climate and weather extremes are increasingly driving displacements.	**3^{0}C - 2070 ±** **4^{0}C - 2090 ±**

Conditions which will make things worse everywhere

The above pages simply summarize a large body of evidence that global-scale effects from the Earth's Energy Imbalance seem likely to force major migrations and societal disruptions.

That isn't the whole story, by a long shot. Big changes are also anticipated (and, indeed, are already unfolding for all to experience) which will continuously and forcefully disrupt life - even in "Human Niche" Regions.

These make the disruptions and migrations from global warming only more likely to occur - they add to the deeper misery.

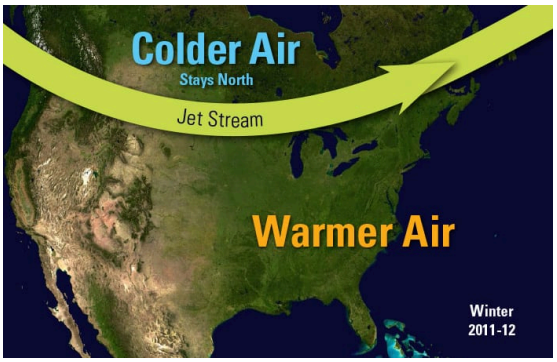
CONDITIONS WHICH WOULD CAUSE CONTINUOUSLY DISRUPTED LIVING, even in "Human Niche" Regions:

5. **Increasingly Erratic and Intense Weather**
6. **Rising Sea Levels**
7. **Tipping Points and Compounded Impacts**

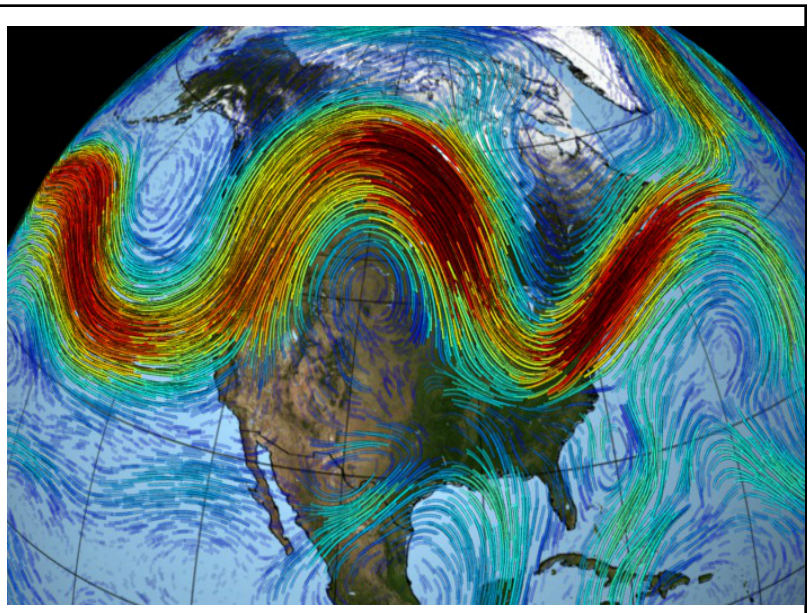
These effects are addressed below, again in summary form:

5. Globally Increasing Erratic Weather (has already started)

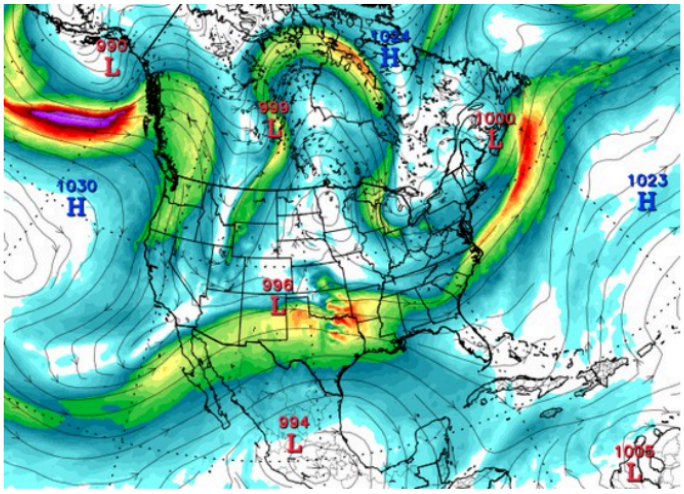
With Warming, the poles warm faster than the equator, weakening the jet stream, allowing large kinks to develop, bringing radically changing weather stimulated by intensification of temperatures and precipitation patterns.[9]



Until recent decades, the jet stream's dominant behavior was gently wavey, but generally stable. With warming, waves in the jet stream are far more commonly dramatic. Patterns can stall for long periods, further intensifying the effects.



The weird jet stream



The jet stream pattern shown by the American model — valid Thursday night — shows the northern branch of the jet bulging north over central Canadian forming a heat dome while the southern branch zips over the southern United States, energizing storms. (TropicalTidBits.com)

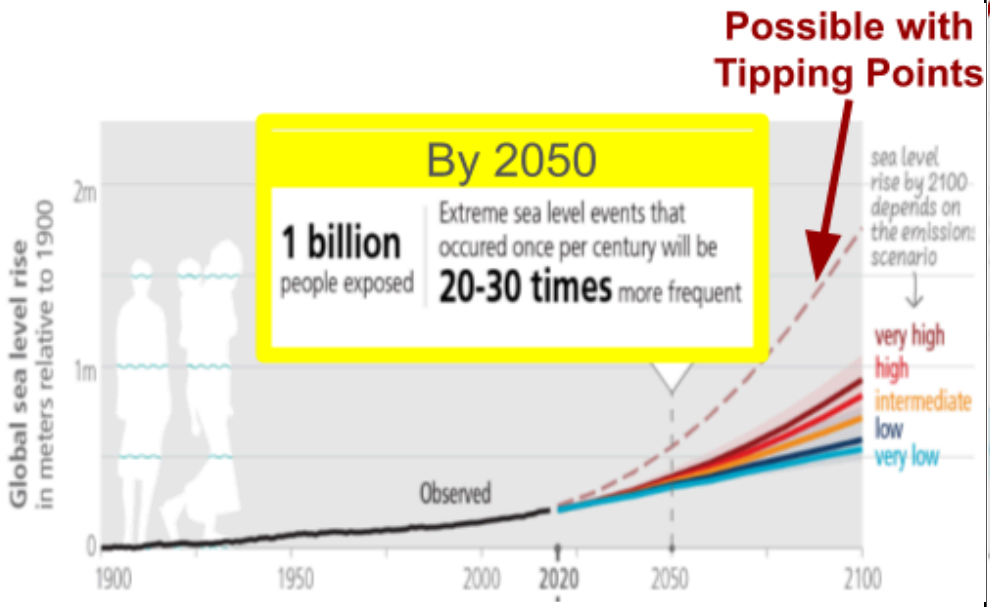
These weather patterns couple with the dramatic climate shifts described earlier. Extreme temperatures and intensified precipitation add to the severity of these realities. All these effects continuously "dial up" with warming.

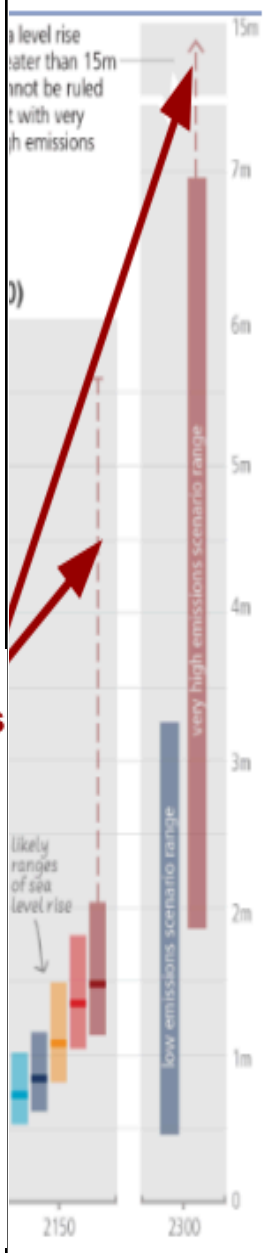
6. Rising Sea Levels and Extreme Sea Level Events (Already Started)

We are currently on the **"Very High" trajectory** shown below. This could result in a meter of (average) SL change this century and up to 7 meters in a couple of centuries. As a direct result, Extreme Sea Level Events will be occurring much more frequently even within a couple of decades, exposing a billion people. [10] O The **dashed lines** reaching to 15m and above are relevant to potential "Tipping Points" to be covered next.

Extreme sea level events add on to the simple rise of sea levels. Storm surges from high winds and lower air pressures add to the higher sea level itself. These can cause the most damage.

The extremely low atmospheric pressure below the storm lifts the sea level like a vacuum cleaner. As the storm hits land, the surge can bring sea levels up far above any protections.



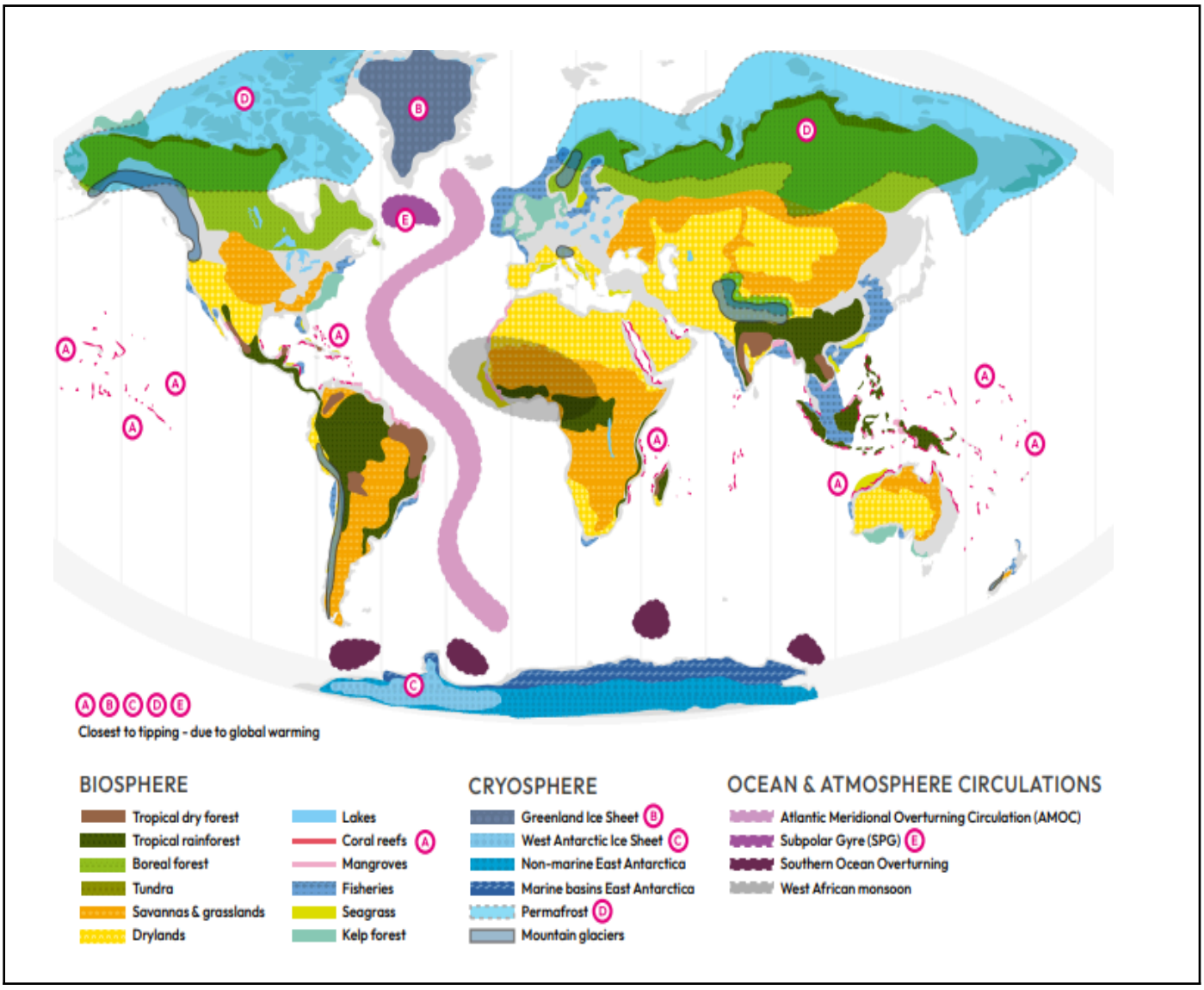


7. Tipping Points (Getting close and will compound)

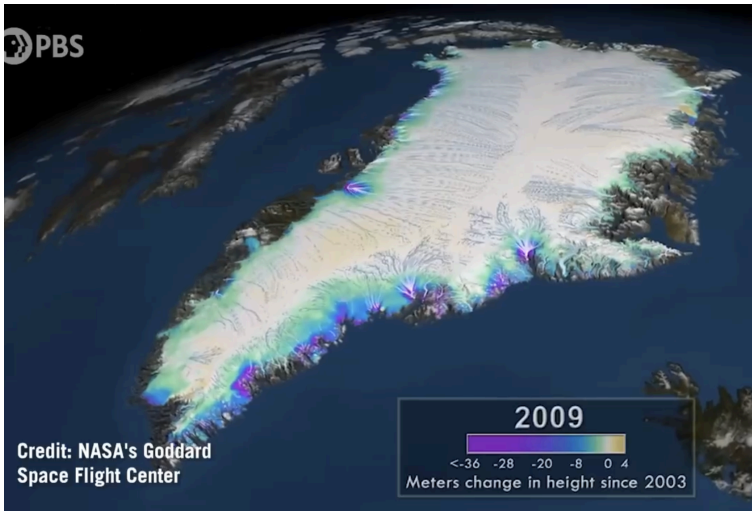
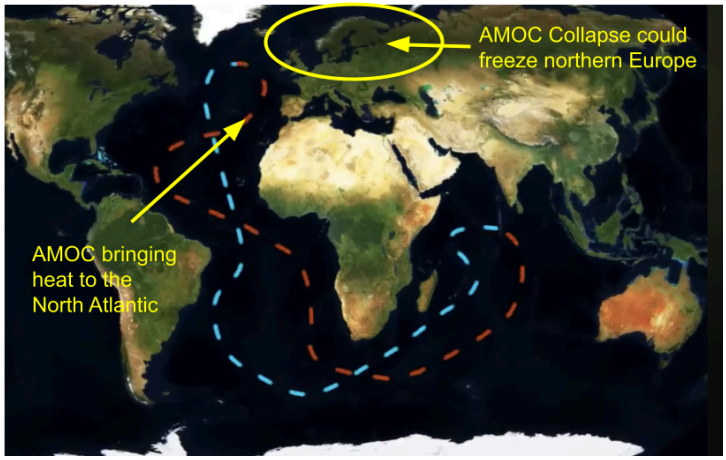
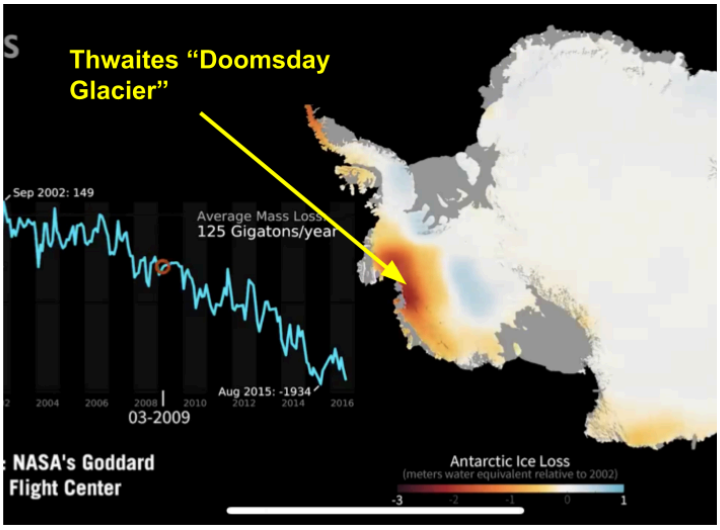
Risks associated with large-scale singular events or tipping points, such as ice sheet instability or ecosystem loss from tropical forests, transition to a high risk between 1.5 and 2.5 C and to very high risk between 2.5 to 4 C.

26 Potential Tipping Points have been carefully assessed. [11 P] Five were flagged as near to tipping, including the **Greenland and West Antarctica Ice Sheets** (irreversibly adding 6 meters of sea level rise over a long period (see Item 6-Sea Level Rise, above), and likely to tip in the next several decades), before we hit 3 C Warming..

It is important to note that a tipping point itself only makes recovery impossible. The full playout of its impacts could take decades to centuries, particularly for melting ice sheets. With respect to the AMOC (see below), a shutdown could have very early impacts.



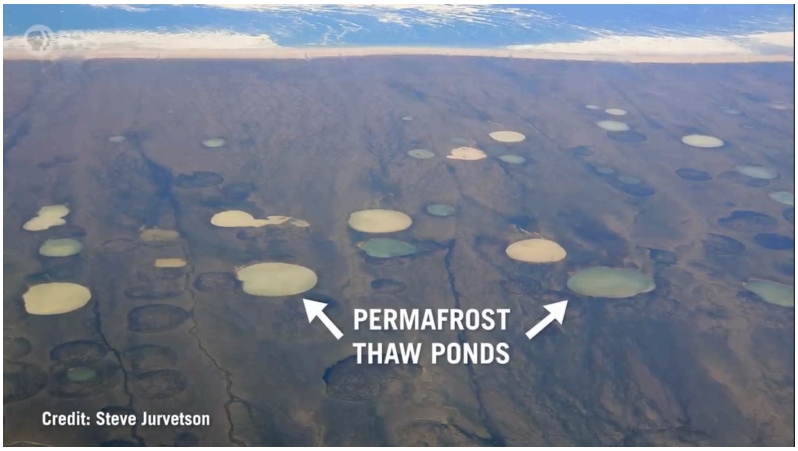
The following table incorporates graphics and info from a 2023 PBS science presentation[11] and the more authoritative major “Global Tipping Points” (GTP) report [11] of December 2023.

Tipping Point #1 **Greenland Ice Sheet - GIS** **(Could tip as soon as 1.5 ^{O}C)** **Possible by 2025 ±** The GIS may well be tipping now. GTP[11] estimates **0.8-3.0 C** for tipping **and 3m Sea Level Rise**. Global impacts.	
Tipping Point #2 **Atlantic Meridional Overturning Circulation - AMOC** **(Could tip as soon as 1.1-2 ^{O}C)** **Possible by 2040 ±** AMOC (responsible for keeping North and Western Europe warm) is measurably slowing. Collapse of this circulation would have **disastrous effects in the North and globally**.[12] 15% recent slowdown.	
Tipping Point #5 **West Antarctic Ice Sheet - WAIS** **(Could tip as soon as 1.5 ^{O}C)** **Possible by 2040 ±** The Western AIC is being more rapidly undercut than expected. GTP[11] estimates between **1.0-3.0 C and 3m Sea Level Rise**. Global impacts.	

Tipping Point #6
Permafrost

(Could tip as soon as 1.5 ^{O}C)
Possible by 2040 ±

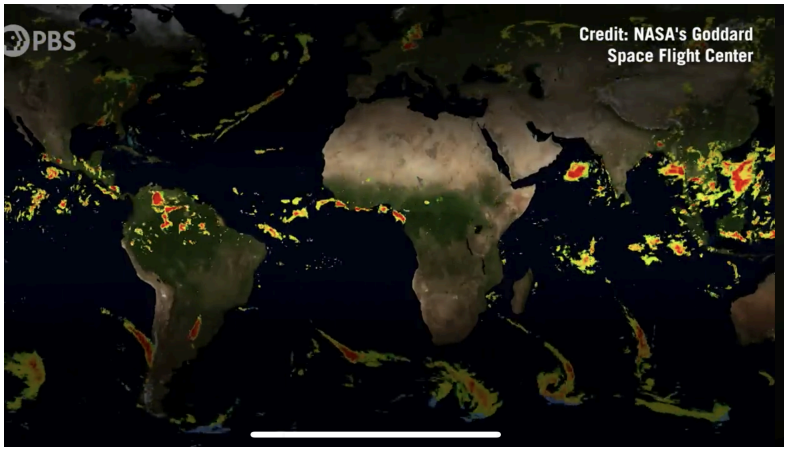
Ecosystem disruptions and large methane emissions. Many signs of deterioration. Could go on multidecadal to century timescales. Global impacts.



Tipping Point #3
Global Monsoons

(Could tip as soon as 2-3 ^{O}C)
Possible by Midcentury ±

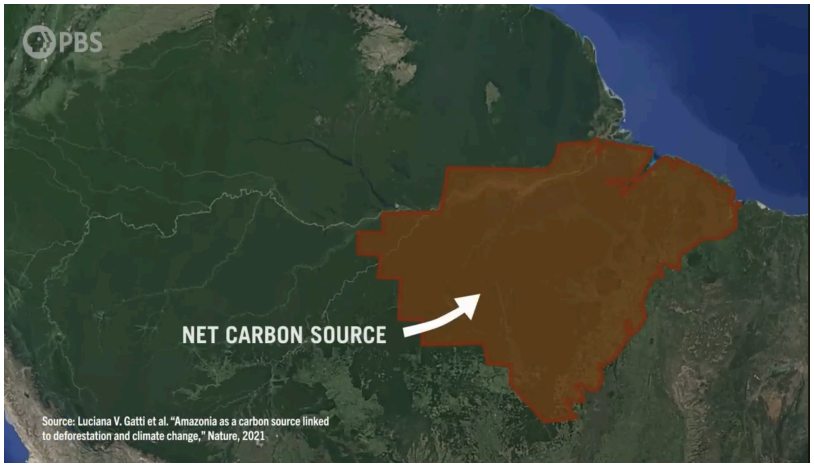
Already experiencing regional disruptions of crop monsoons. Will have **major impacts on productivity and human wellbeing**.



Tipping Point #4
Amazon Rainforest

(Could tip as soon as 2-3 ^{O}C)
Possible by Midcentury ±

Already have lost a large part of the Amazon to drought and clearcut, **becoming a carbon source**, instead of a carbon sink.



While these Tipping Point names all suggest a local impact, all have enormous implications globally. Furthermore it appears likely that they are not at all independent of each other - cascading impacts are anticipated.

Conclusions:

TIMING of these benchmark Temperature changes

Without global changes in behaviors, the **TIMING** of Temperature Increases above pre-industrial times is likely to fall into these approximate ranges:

Approx Year	Global Warming
2030 ±	1.5 ^{0}C = 2.7 ^{0}F (may be there now)
2040 ±	2.0 ^{0}C = 3.6 ^{0}F
2070 ±	3.0 ^{0}C = 5.4 ^{0}F
2090 ±	4.0 ^{0}C = 7.2 ^{0}F
2120 ±	5.0 ^{0}C = 9.0 ^{0}F

IMPACTS at these Temperature changes

Societal disruptions have begun and will only get worse with additional warming of the planet. People and Species are being driven from their current locations, and globally the erratic and intensified weather is challenging even regions which are not yet uninhabitable. By 2040 - 2070 global disruptions and migrations could be expected.

At our current
fossil fuel emissions trajectory,
we'll likely have

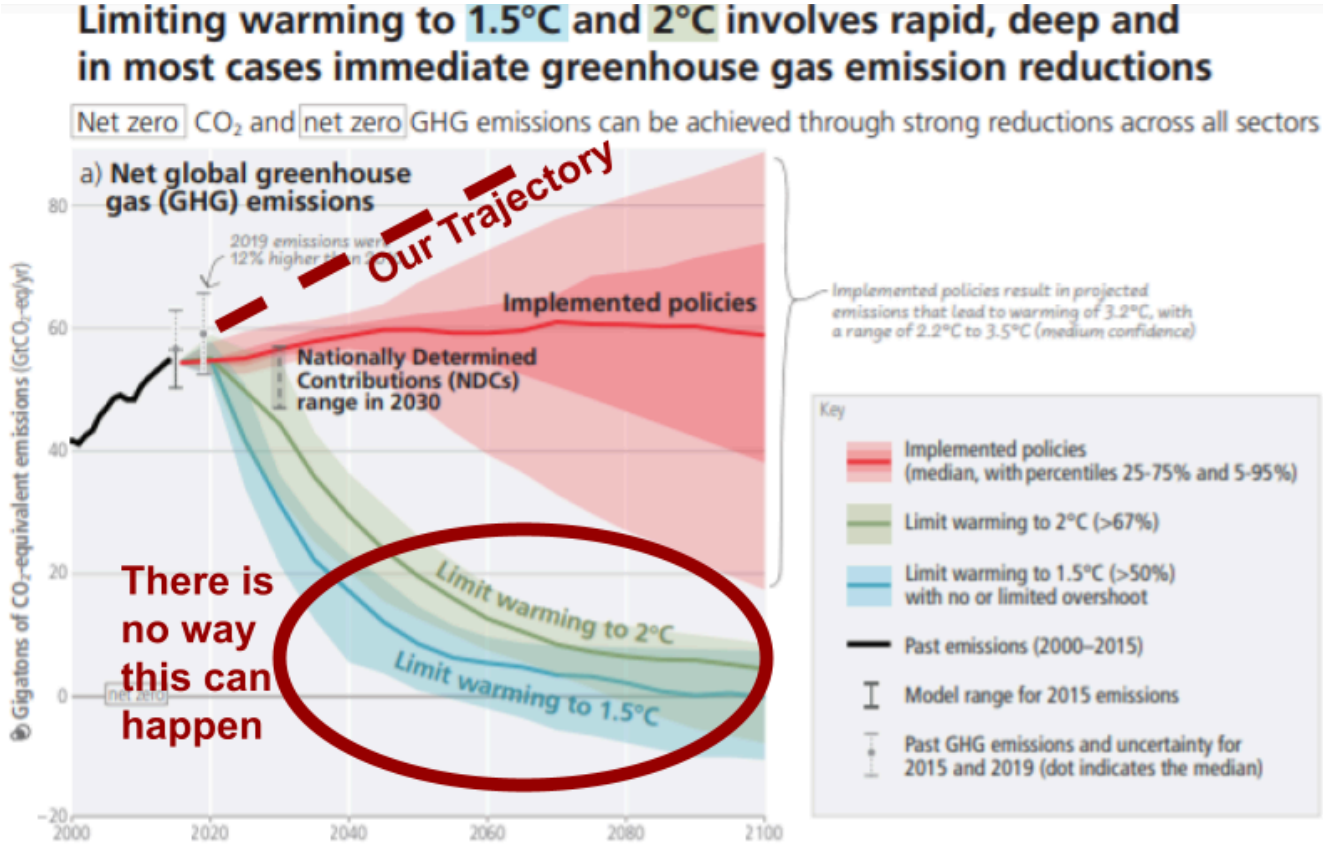
Global Societal Disruption by 2040 - 2070

And the disruption is already starting…

To change this, we would have to change our path.

My Perspectives:

- The future built on our current trajectory of burning fossil fuels is too awful to accept.
- Every strategy for stopping Temperature Increases MUST be pushed HARD.
- Societies are locked into non-cooperation at this point.
- The necessary reductions in greenhouse gas emissions, including CO_2, appear impossible to me without a major disruption of attitudes - nowhere to be seen yet. Compare the chart below to our current emissions trajectory discussed on page 4 [t].



Necessary changes:

1. FUNDAMENTAL: Carbon Emissions must be stopped and removed
2. National awareness that we have an urgent problem and urgent internal actions to deal with our situation
3. Global Cooperation for Drastic and Urgent Emissions Cuts
4. Global Coordination of Migrations, which have already started

References

The most comprehensive compilation of this research is to be found in the reports of the Intergovernmental Panel on Climate Change (IPCC), which may all be accessed at: https://www.ipcc.ch/reports/ . The state of understanding (compiled in many thousands of pages based on many thousands of scholarly studies) as of March 2023 is summarized in the IPCC's *AR6 Synthesis Report: Climate Change 2023* at: https://www.ipcc.ch/report/sixth-assessment-report-cycle/ .

Most of the information provided in this present study comes directly from the *Synthesis Report* as well as from materials which fed into it, including *Climate Change 2021 - The Physical Science Basis* at: https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/ and *Climate Change 2022 - Impacts, Adaptation and Vulnerability* at https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/ . Additional material is brought in from more recent scientific work and from simple charts I have made from the IPCC and scientific materials. All materials are referenced at the end of this Study.

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15. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Annex-I.pdf