Climate and Human Health Responders Course for Health Professionals

Climate Change for the Health Professional

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@OceansClimateCU

Project ECHO

Columbia Mailman School of Public Health
Global Consortium on Climate and Health Education

NOAA

Santé Canada
Health Canada

Climate Change for the Health Professional
Learning Objectives

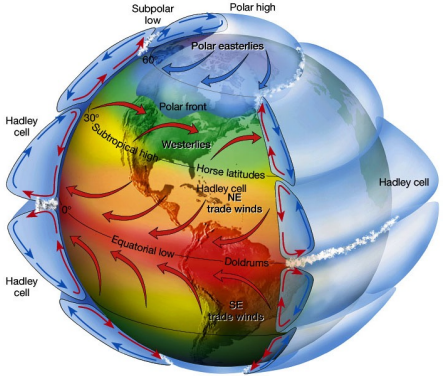
- Describe the difference between *weather* and *climate.*
- Distinguish between *natural climate variability* and *long-term climate change.*
- Explain the general mechanism of the *greenhouse effect.*
- Describe the measurement and evidence base of *climate drivers.*
- Explain the *societal dimensions of climate drivers.*
- Communicate the degree of *scientific consensus* on climate change and become familiar with the IPCC and other core resources.

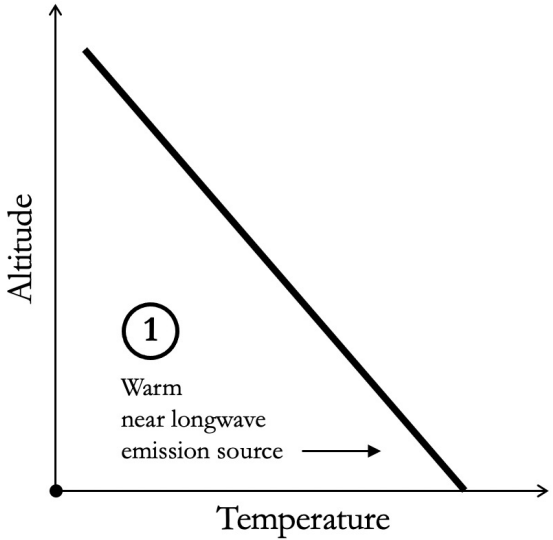
Disclosure Information

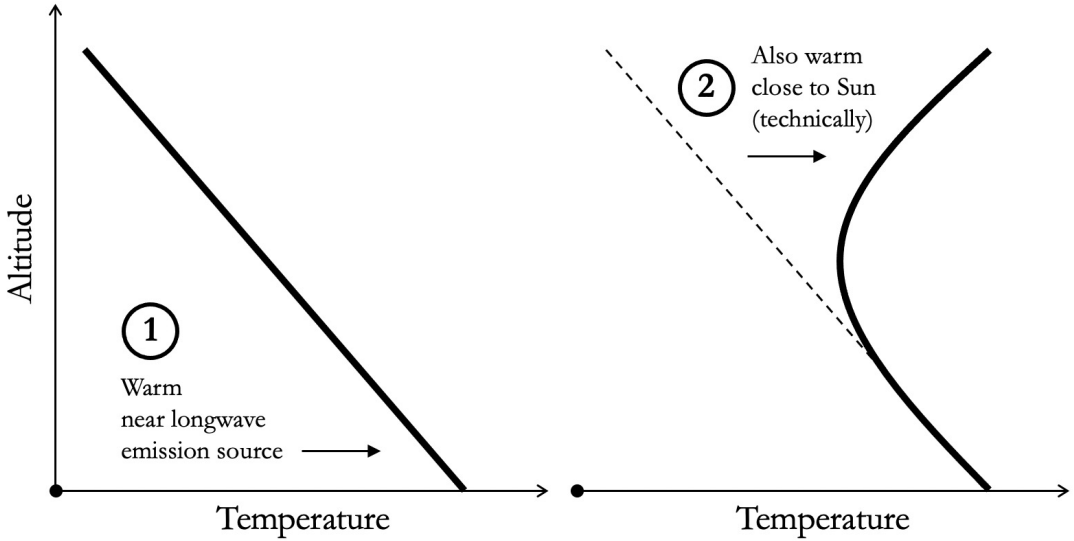
N/A

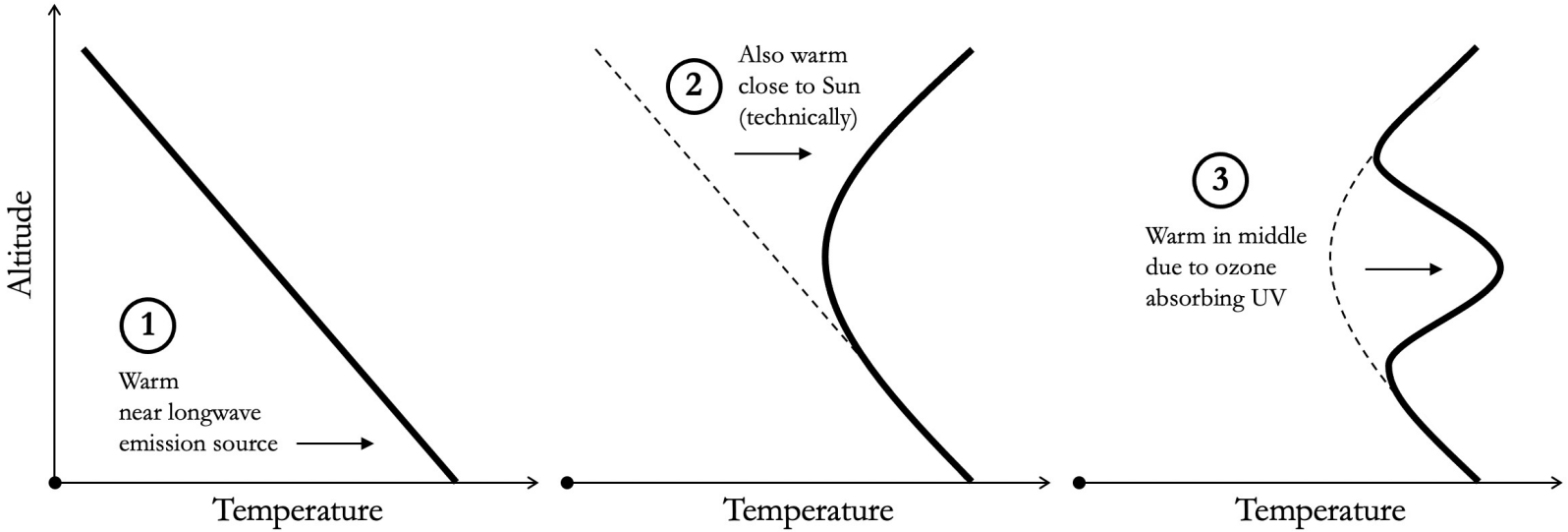
Describe the difference between *weather* and *climate.*

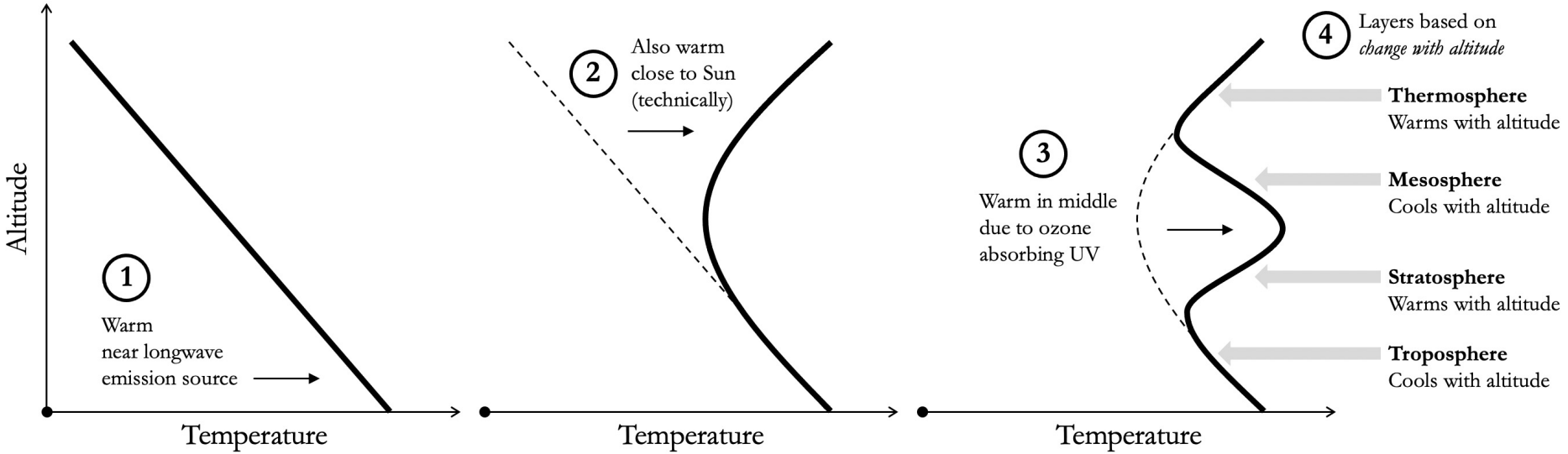
- The atmosphere is 3D. This is important.
- Everything is driven by the global energy balance.
- Weather vs. climate? It's <u>all</u> a gray area.
- Climate is not just "average weather." It's a dynamic system.




Altitude
1
Warm
near longwave
emission source
Temperature


Altitude
1
Warm
near longwave
emission source
Temperature
2
Also warm
close to Sun
(technically)
Temperature


Altitude
1
Warm
near longwave
emission source
Temperature
2
Also warm
close to Sun
(technically)
Temperature
3
Warm in middle
due to ozone
absorbing UV
Temperature


Altitude
1
Warm
near longwave
emission source
Temperature
2
Also warm
close to Sun
(technically)
Temperature
3
Warm in middle
due to ozone
absorbing UV
Temperature
4
Layers based on
change with altitude
Thermosphere
Warms with altitude
Mesosphere
Cools with altitude
Stratosphere
Warms with altitude
Troposphere
Cools with altitude

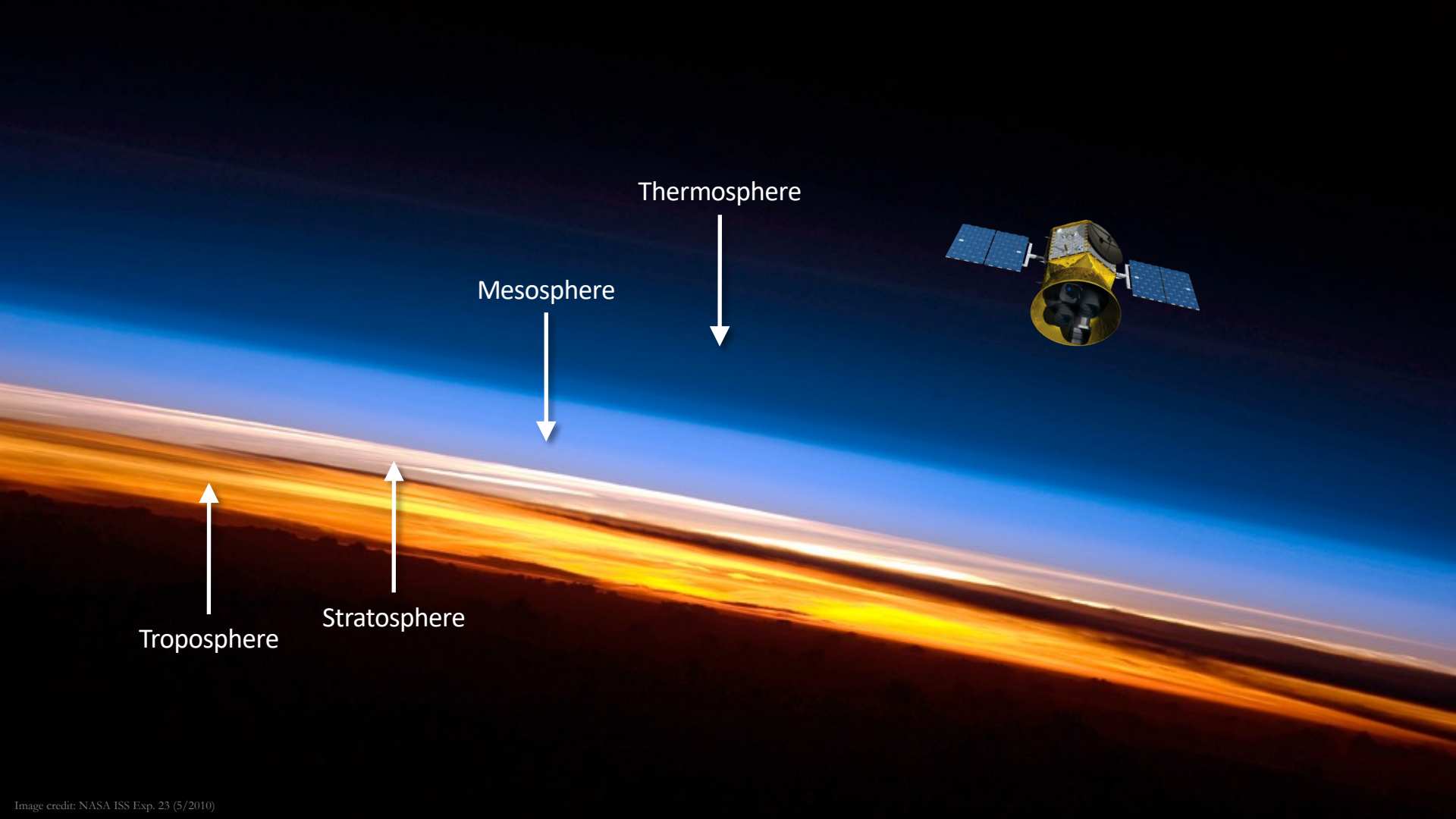
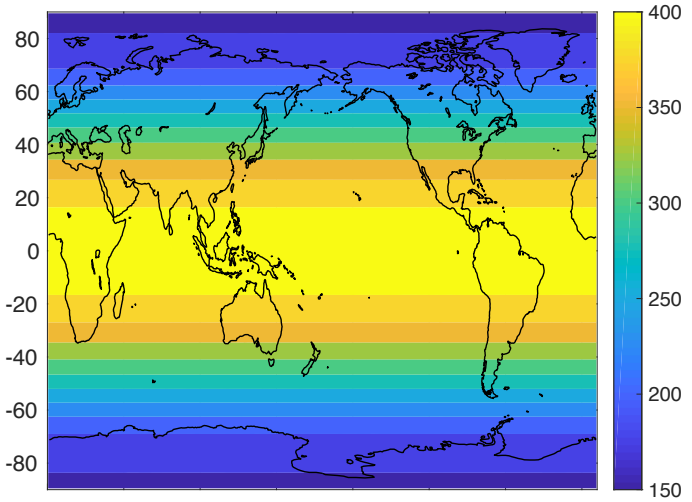
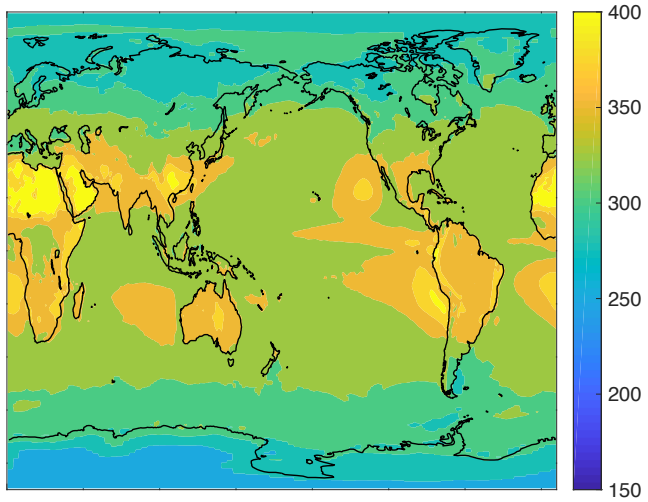


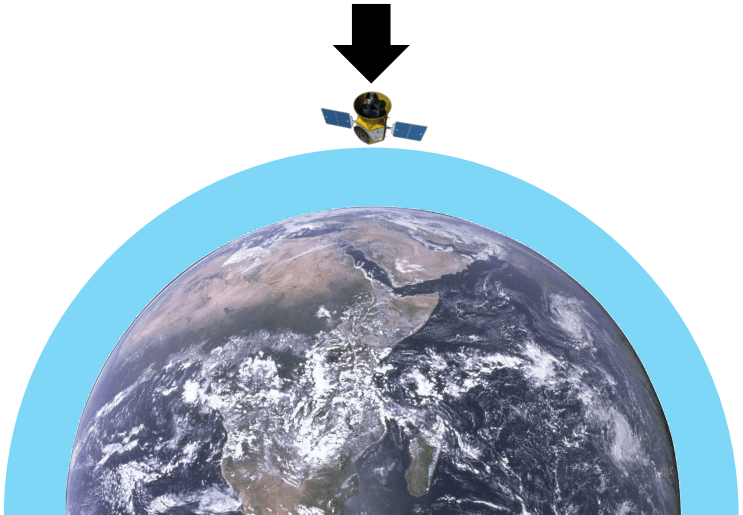
Image credit: NASA ISS Exp. 23 (5/2010)

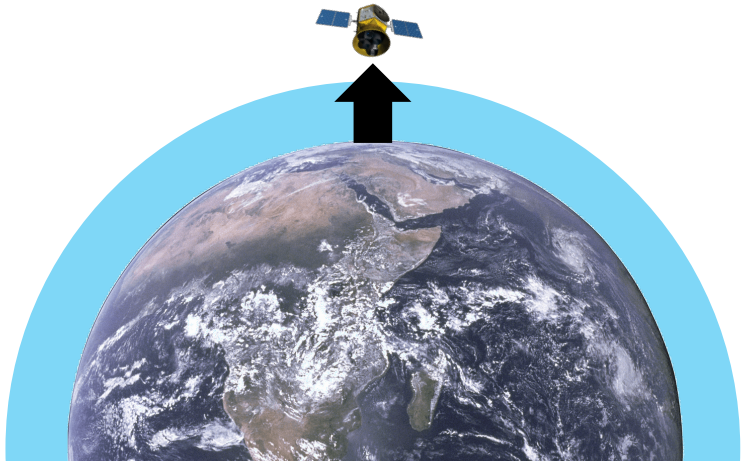
Incoming radiation at top of atmosphere



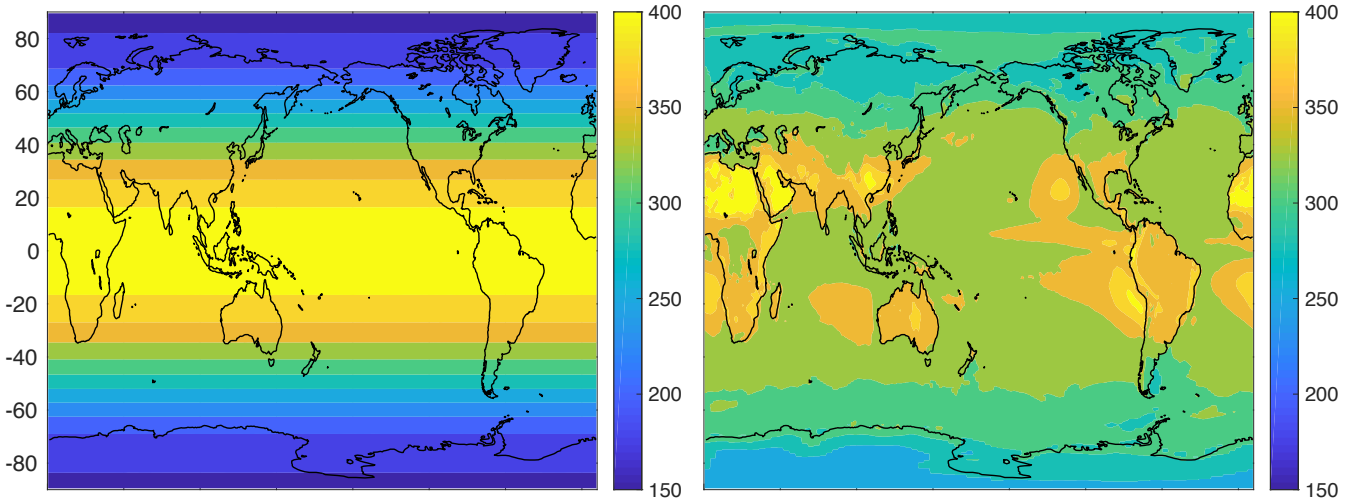


Outgoing radiation at top of atmosphere



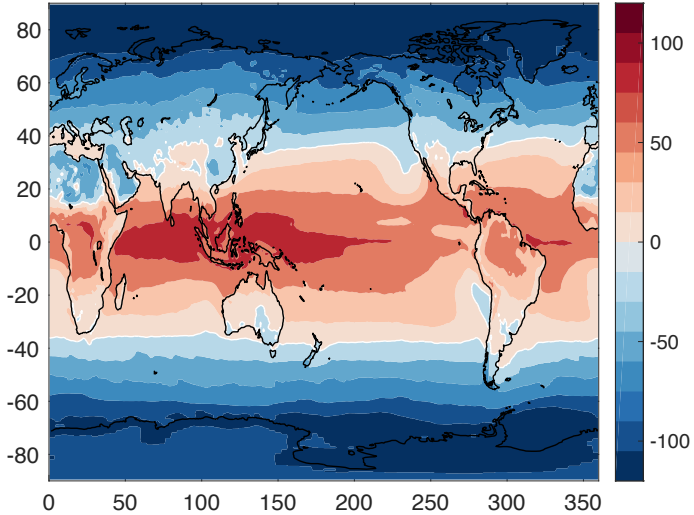


Incoming radiation at top of atmosphere

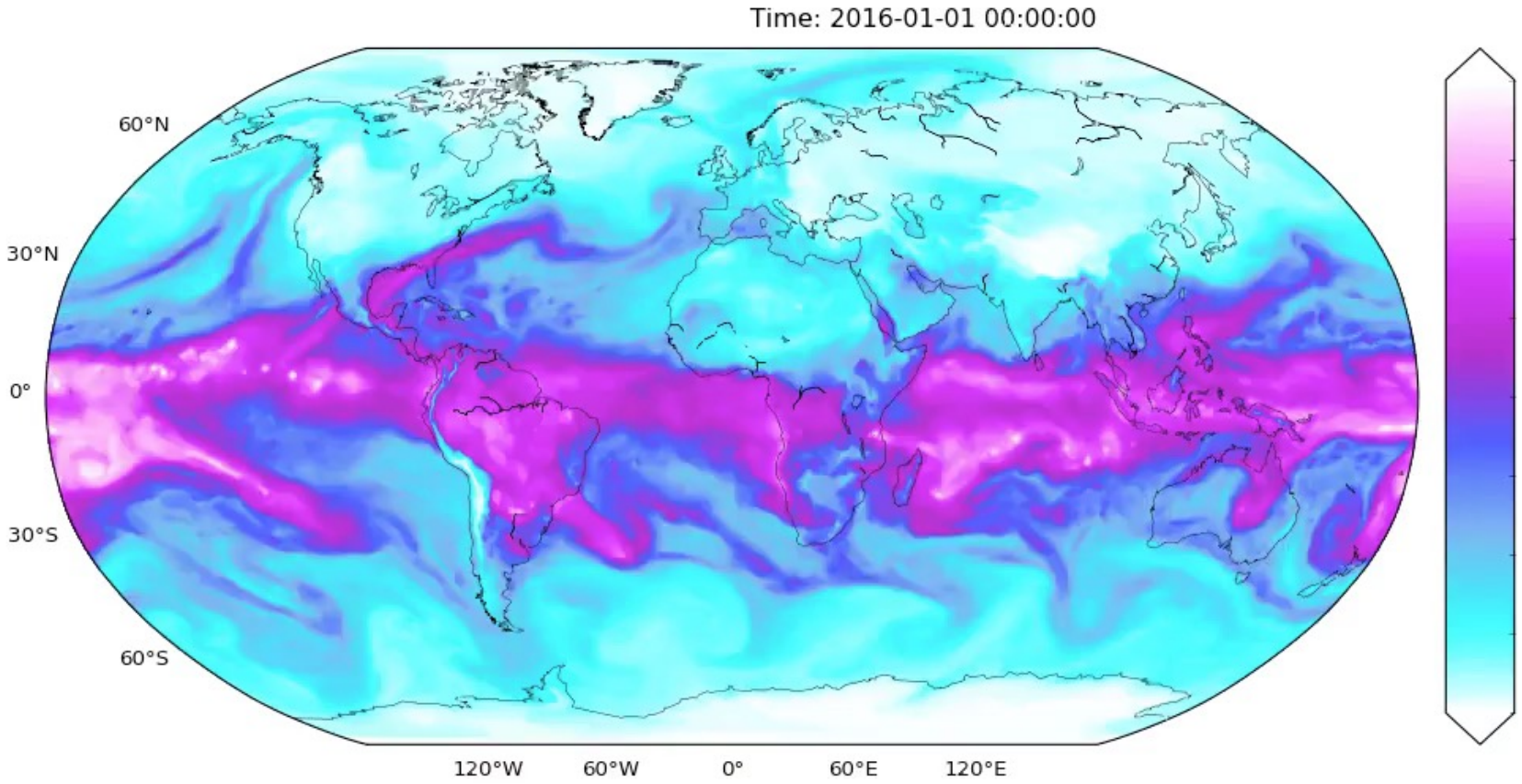


Outgoing radiation at top of atmosphere

Net radiation at top of atmosphere

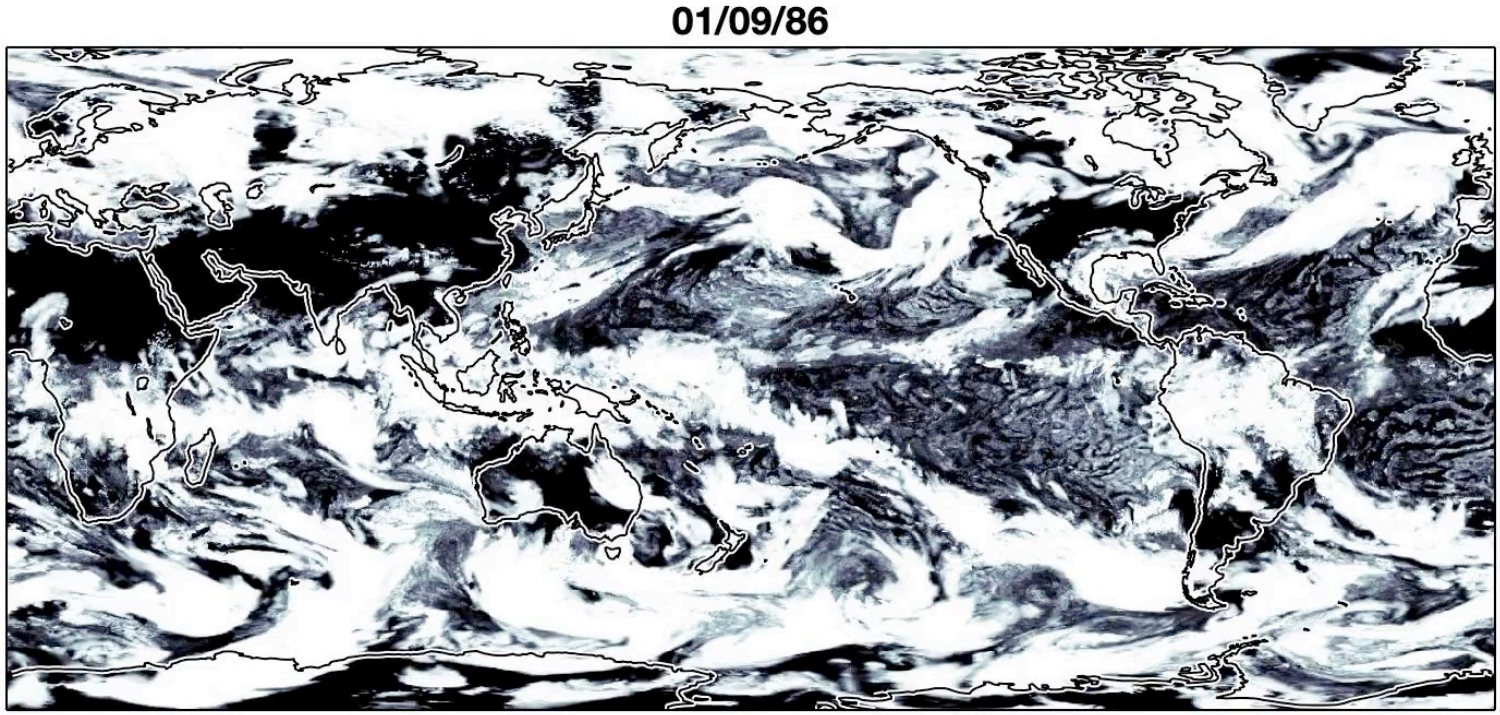


Precipitable water throughout 2016 (one frame every 2 hours)

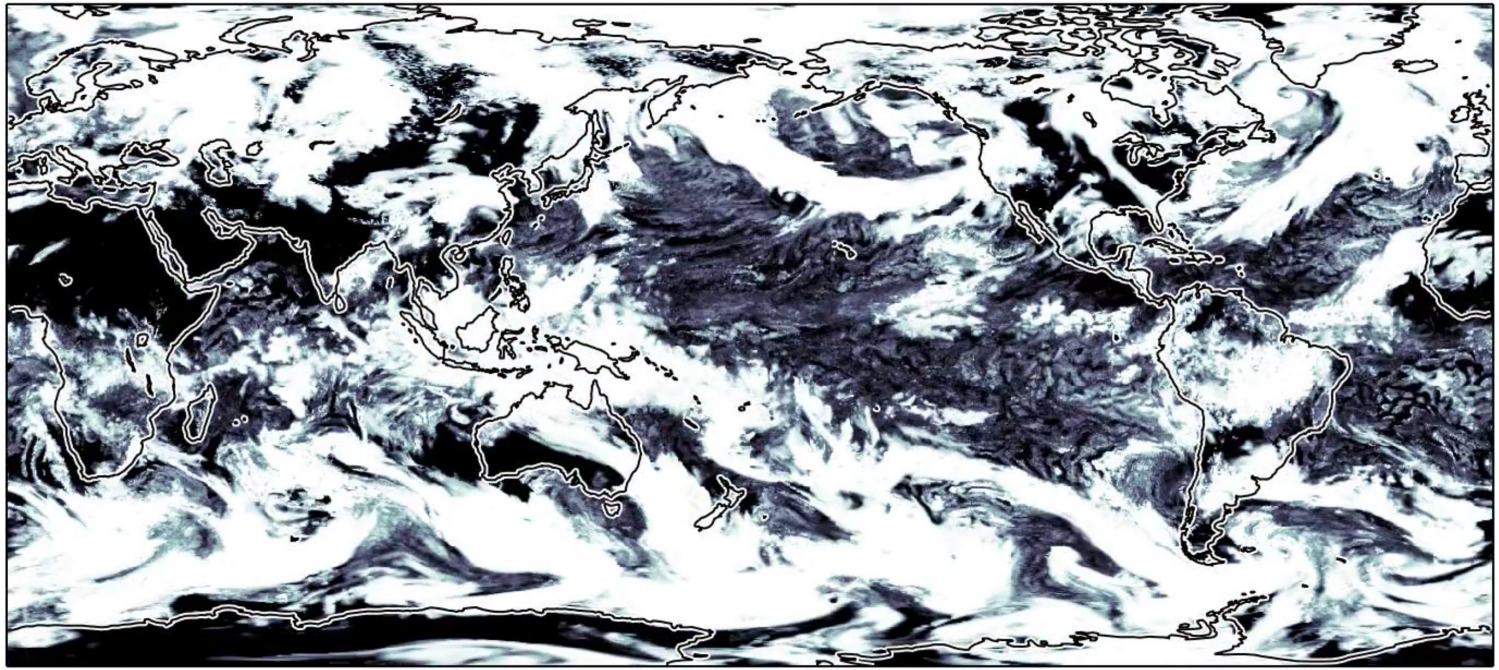


Courtesy James Warner, University of Exeter (@MetmanJames)

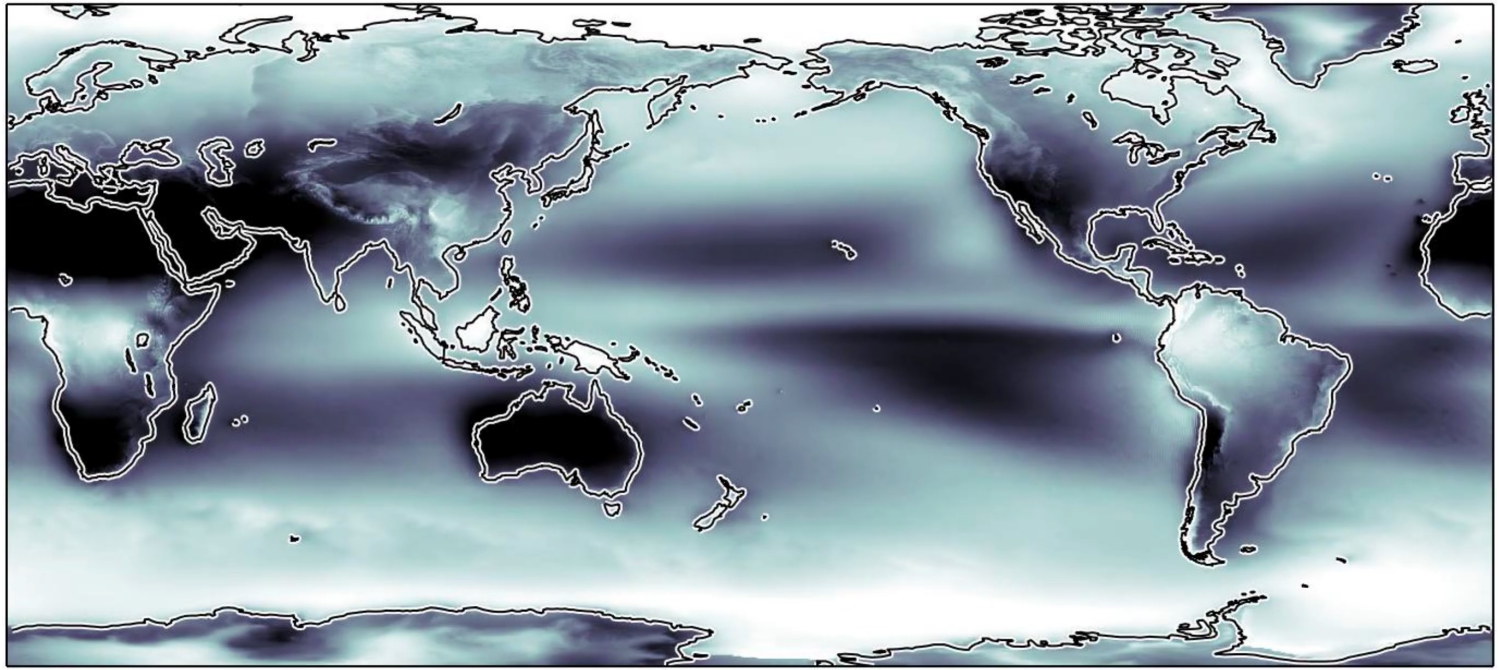
The continuum from **weather** to **climate** (1 hour to 70 years)



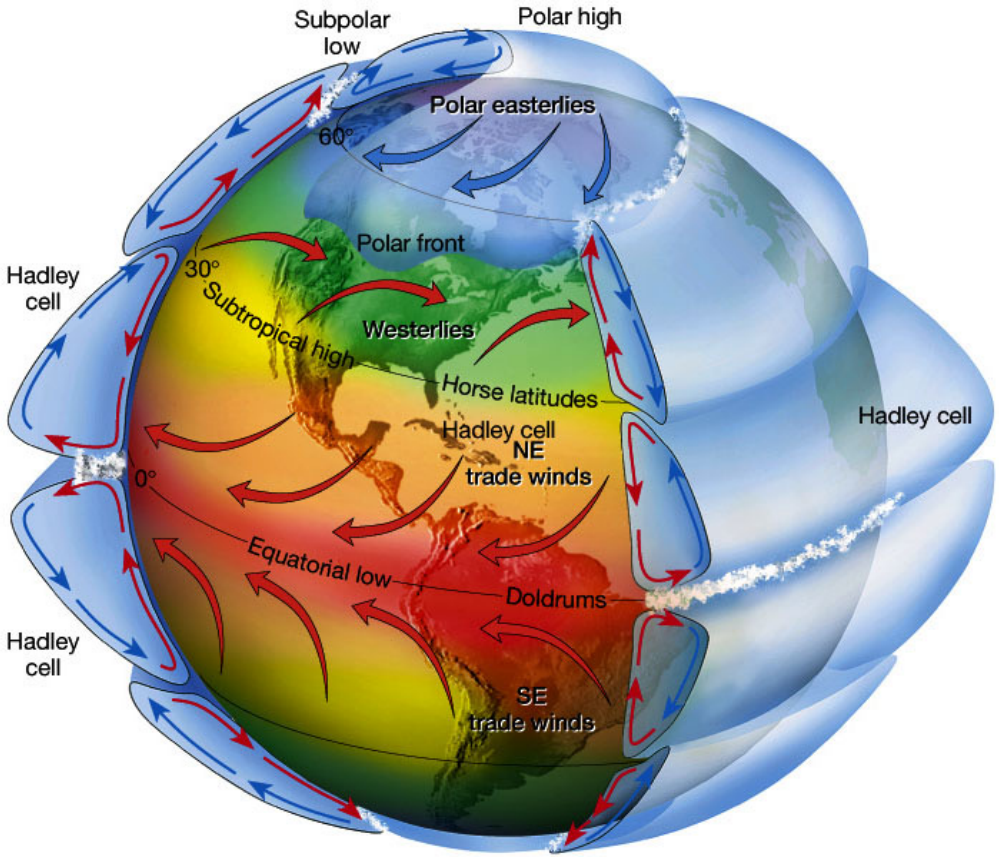
Global clouds over **1 hour**

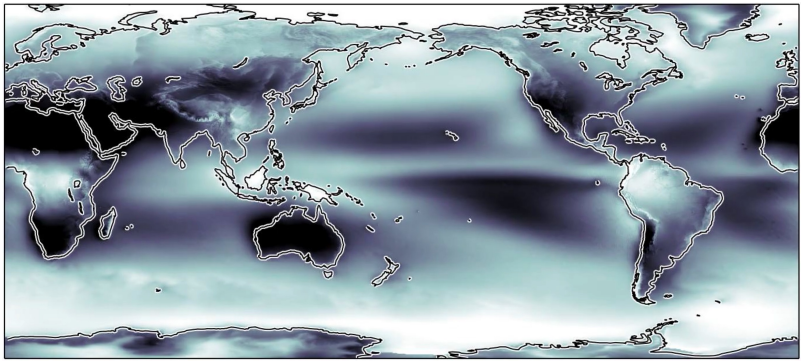


Global clouds over **7 decades**



The atmosphere has a robust **mean** circulation, which sets the global backdrop





Distinguish between *natural climate variability* and *long-term climate change.*

- Weather and climate is a continuum of physical processes. So is the variability and change.
- The real challenge is distinguishing between *natural* and *anthropogenic* long-term climate change (“attribution”).
- We have many tools to do so, including climate models.

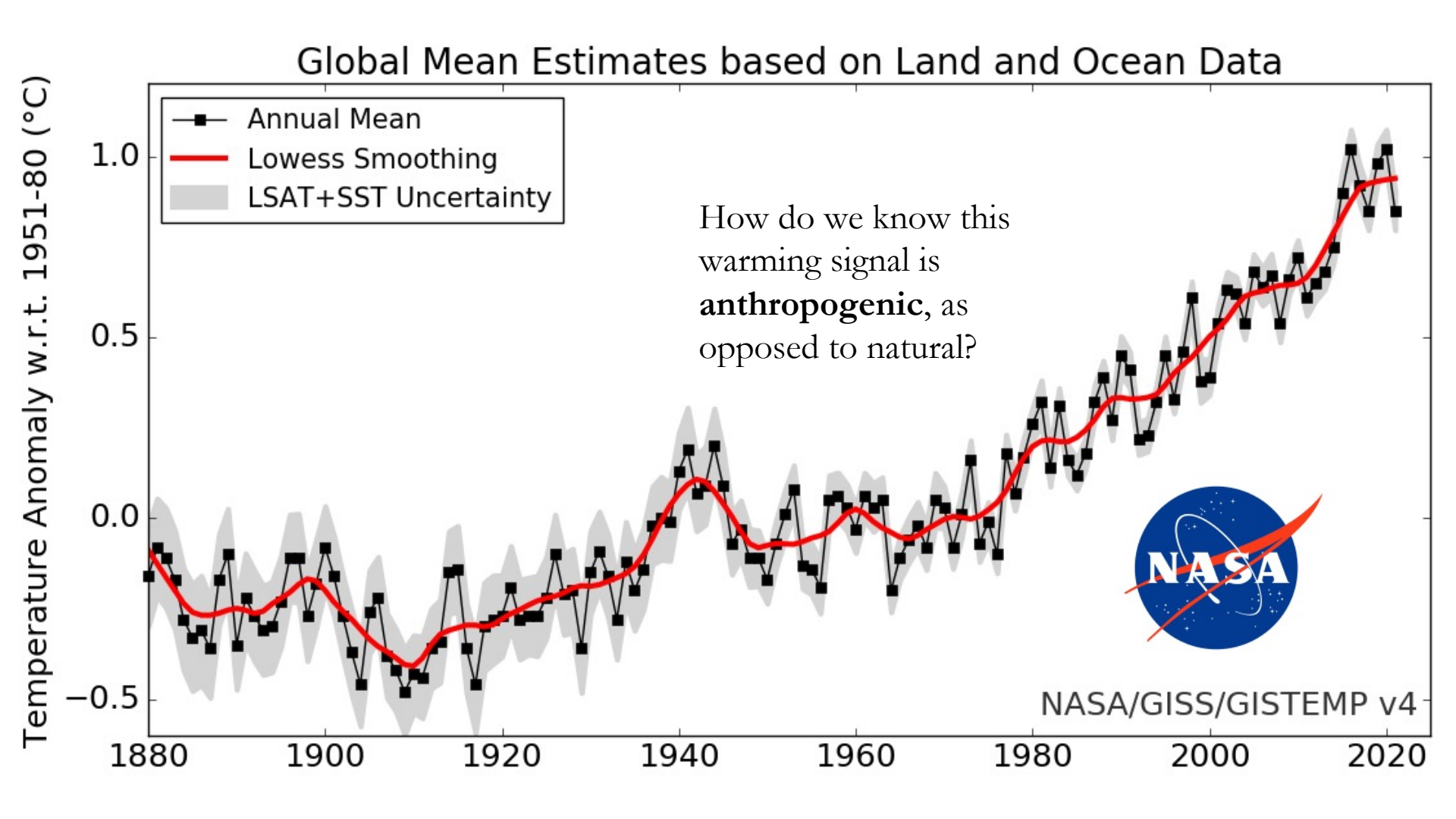
The challenge of *attribution* is that anthropogenic climate change lives here, and it's not alone.

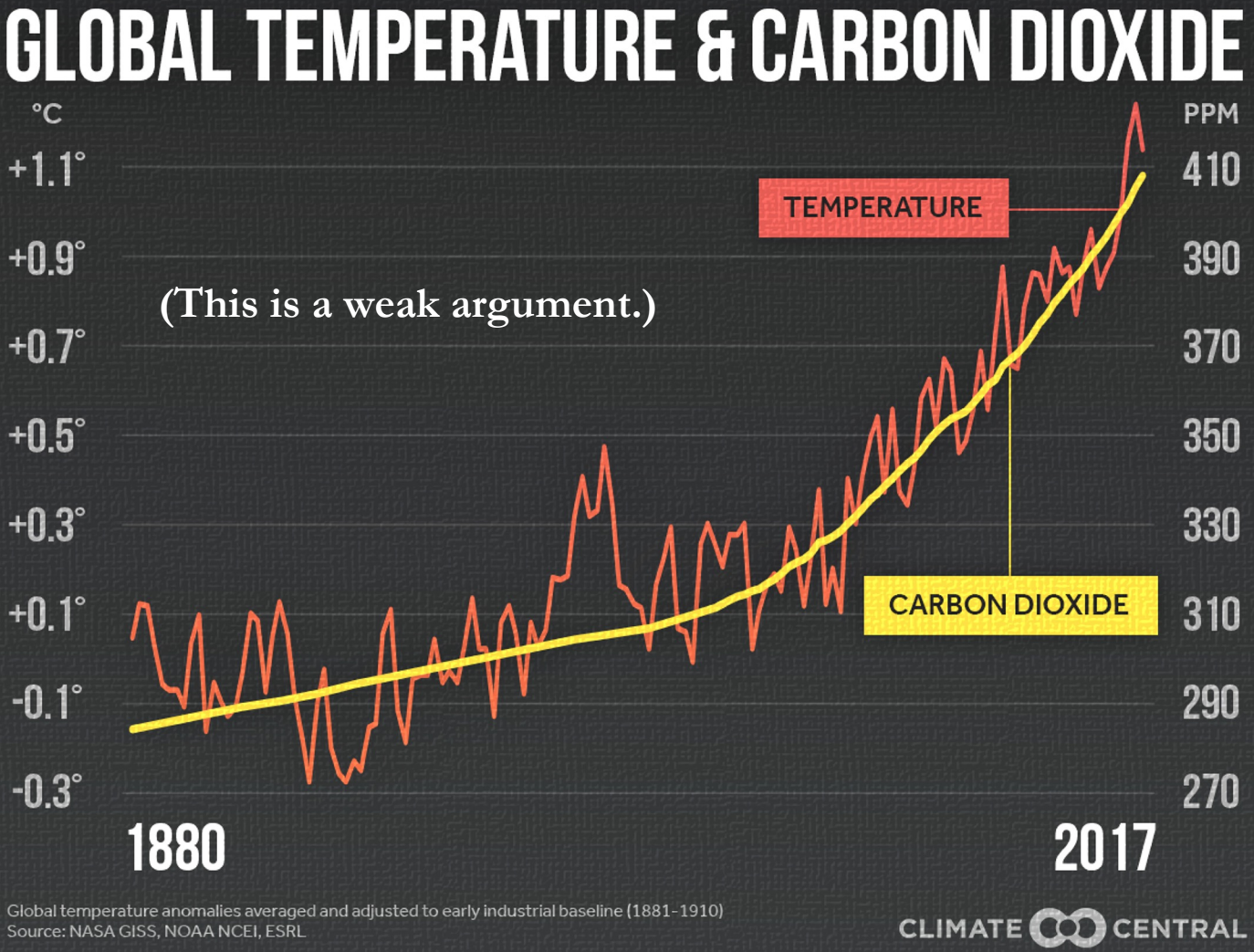
Natural climate variability that humans probably *don't* recognize

Natural climate variability that humans *might* recognize

Weather that humans *easily* recognize

Hours Days Weeks Months Years Decades Centuries Millennia+

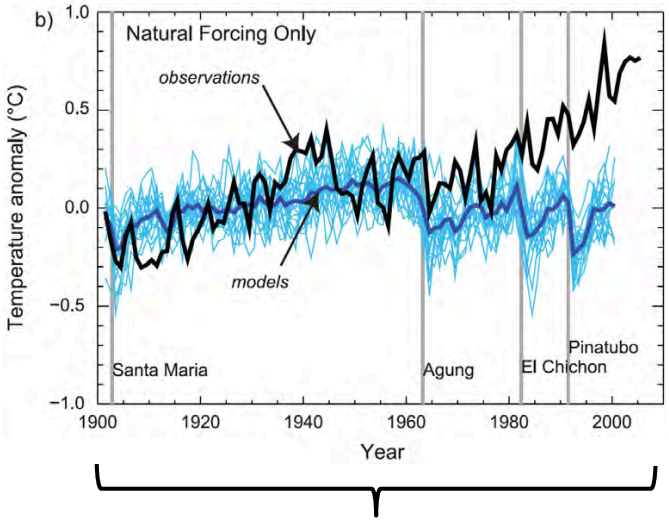

Global Mean Estimates based on Land and Ocean Data
Annual Mean
Lowess Smoothing
LSAT+SST Uncertainty
Temperature Anomaly w.r.t. 1951-80 (°C)
1.0
0.5
0.0
−0.5
1880
1900
1920
1940
1960
1980
2000
2020
How do we know this warming signal is **anthropogenic**, as opposed to natural?
NASA
NASA/GISS/GISTEMP v4


GLOBAL TEMPERATURE & CARBON DIOXIDE
°C
+1.1°
+0.9°
+0.7°
+0.5°
+0.3°
+0.1°
-0.1°
-0.3°
PPM
410
390
370
350
330
310
290
270
TEMPERATURE
CARBON DIOXIDE
(This is a weak argument.)
1880
2017
Global temperature anomalies averaged and adjusted to early industrial baseline (1881-1910)
Source: NASA GISS, NOAA NCEI, ESRL
CLIMATE CENTRAL

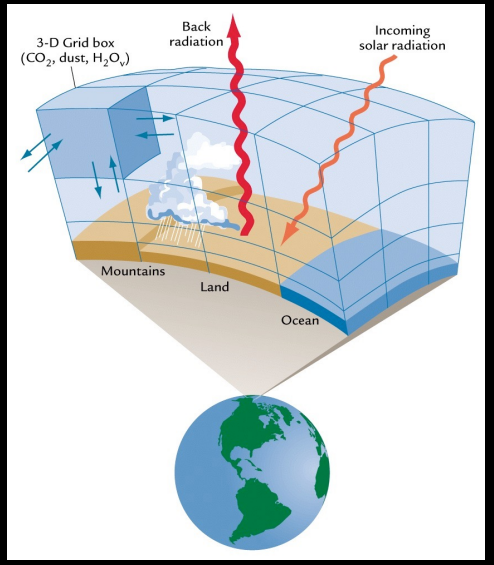
We run global climate models on supercomputers.

Image: https://www.datacenterdynamics.com/en/news/ncars-534-petaflop-supercomputer-cheyenne-comes-online/

Global Warming Attribution with Climate Models



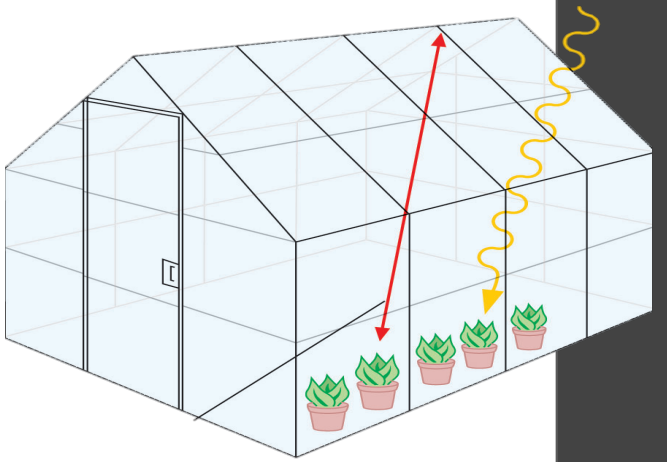
Without Human Emissions



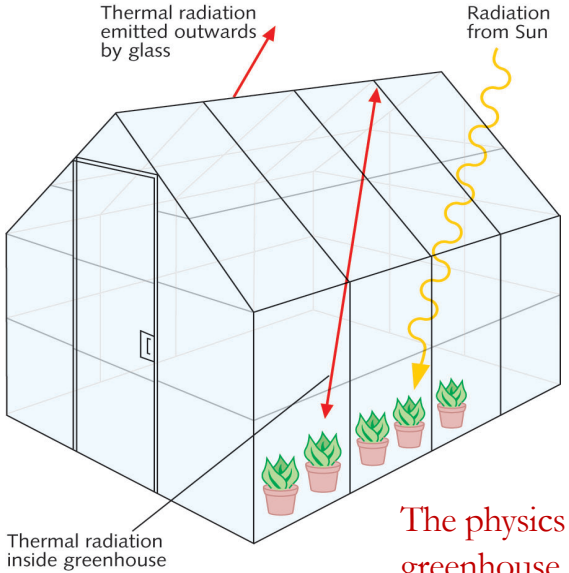
A **global climate model** (GCM) is a comprehensive numerical model that represents the essential processes at work within Earth's atmosphere, ocean, cryosphere, etc. by applying the laws of physics at each "pixel" on Earth.

Explain the general mechanism of the *greenhouse effect.*

- The greenhouse effect reduces the amount of energy emitted to space.
- Since it does not affect the amount of energy gained from the sun, the internal energy (i.e., temperature) must increase.
- We understand it (you can, too).
- We are also measuring it in real time.

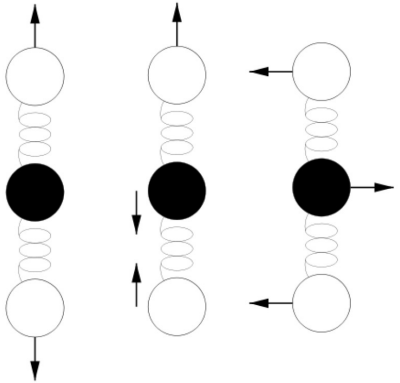


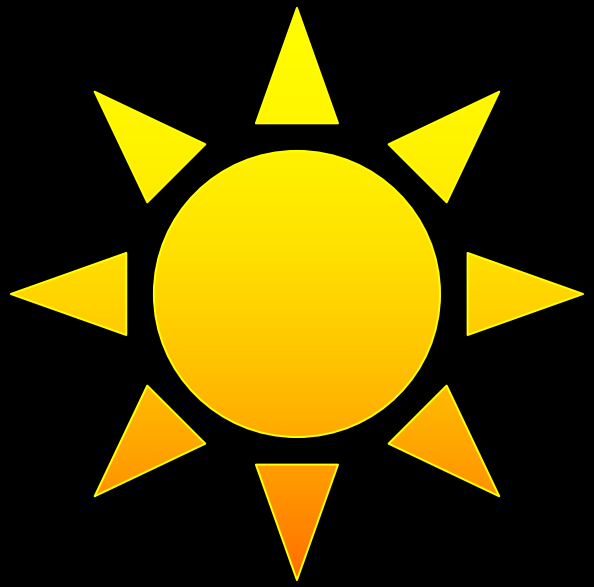
The greenhouse effect is a well–understood scientific process.



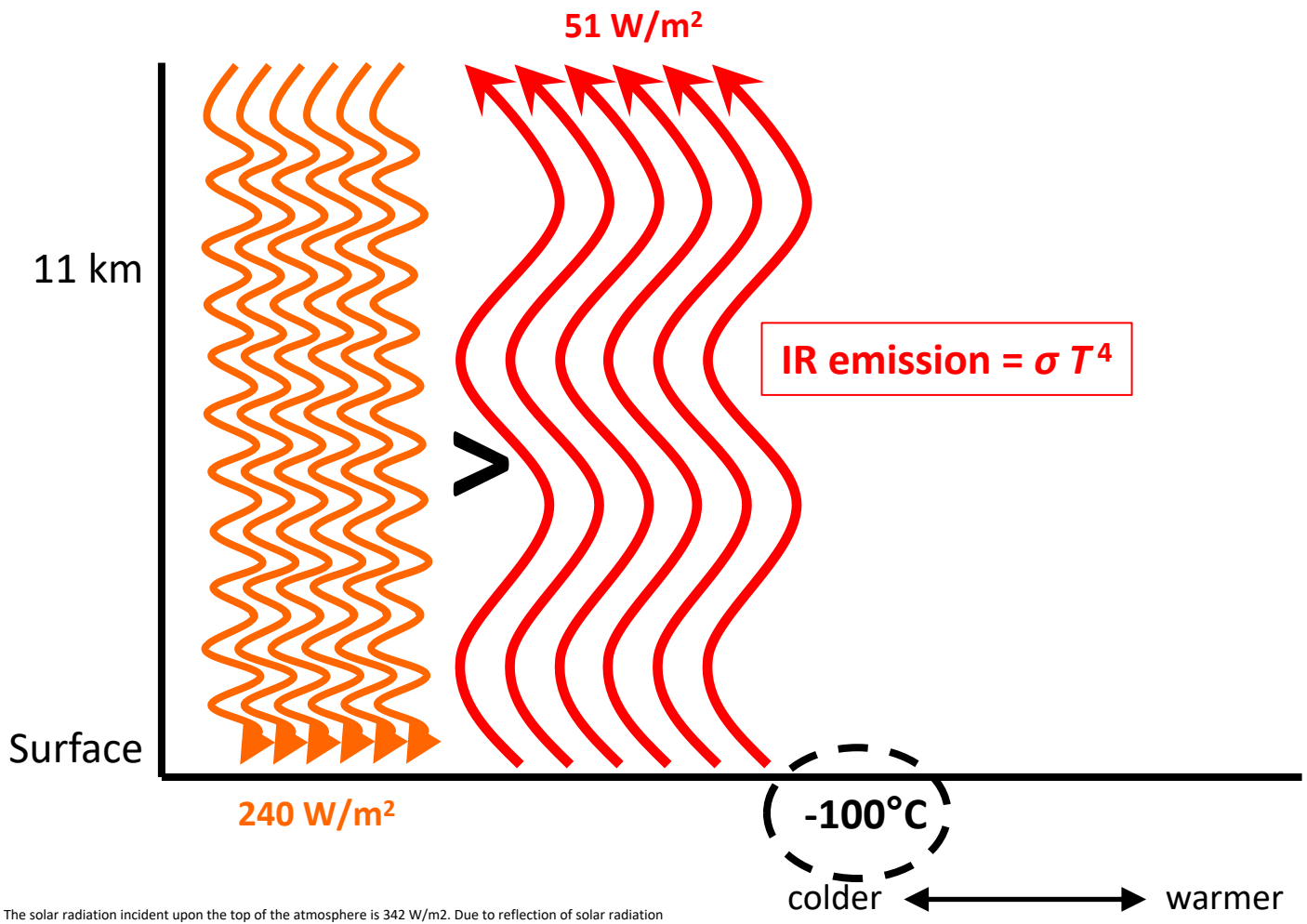
The physics of the greenhouse effect is high school physics.

The molecular structure of CO_2 makes it very effective at absorbing longwave radiation emitted by Earth.

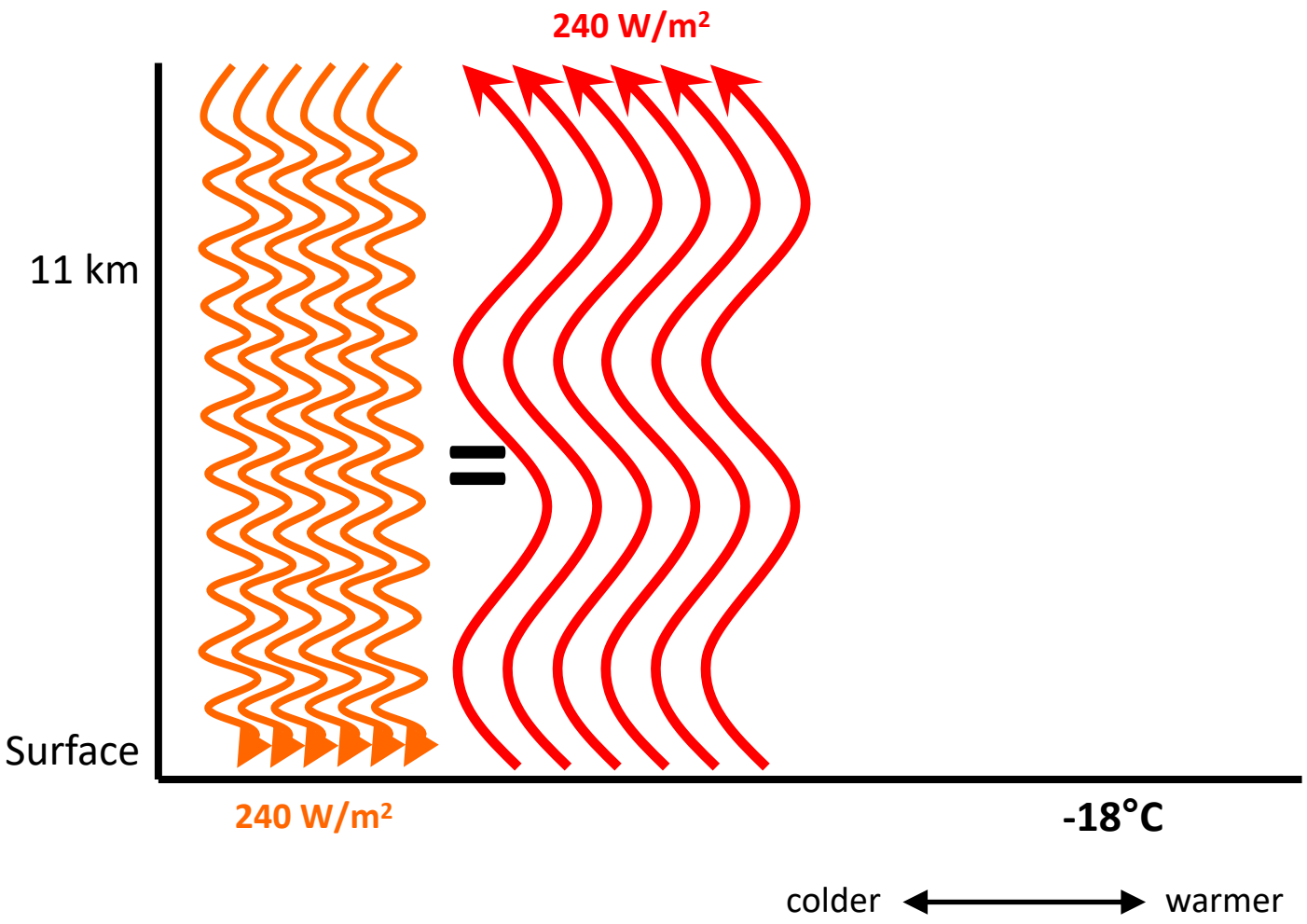


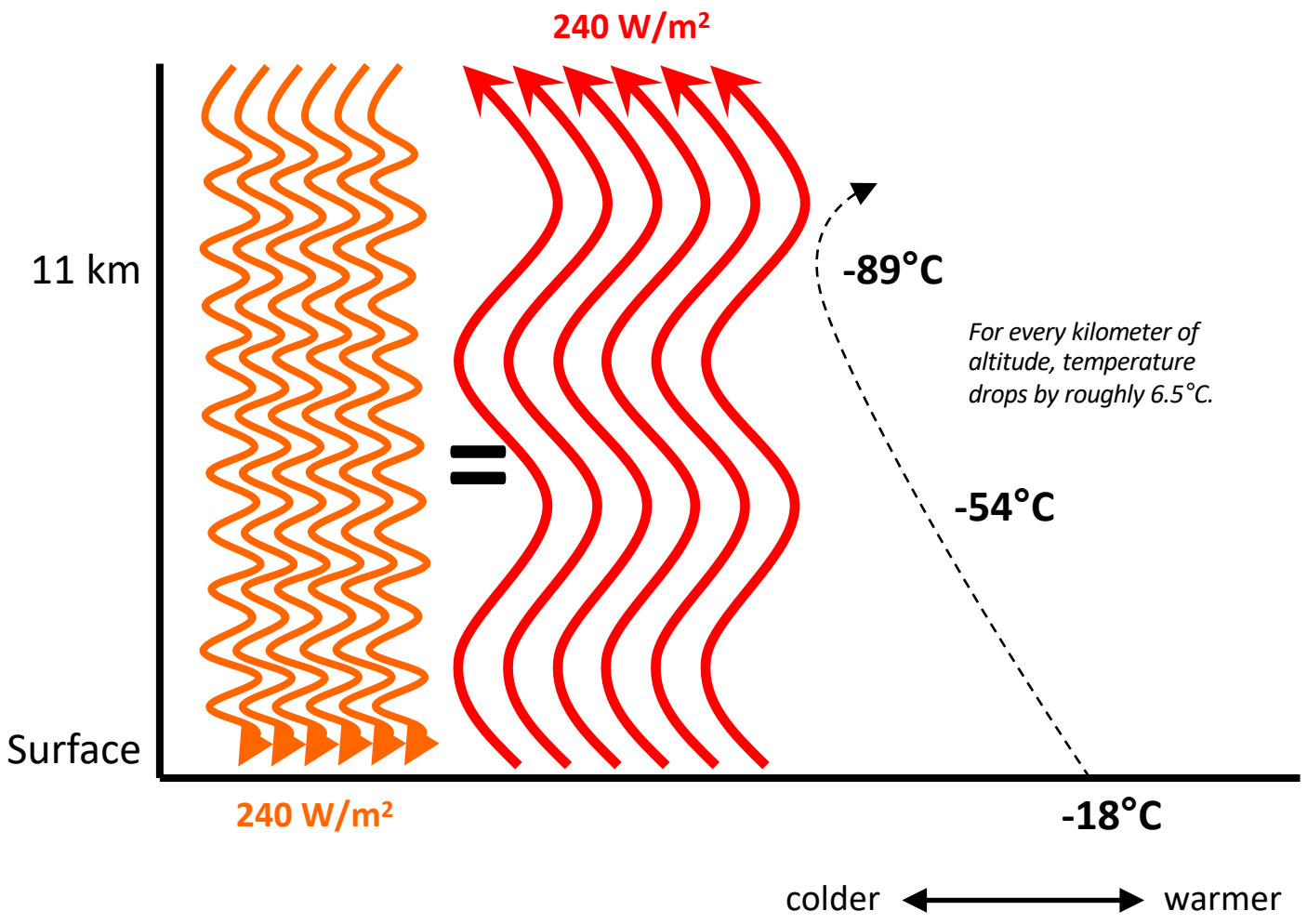


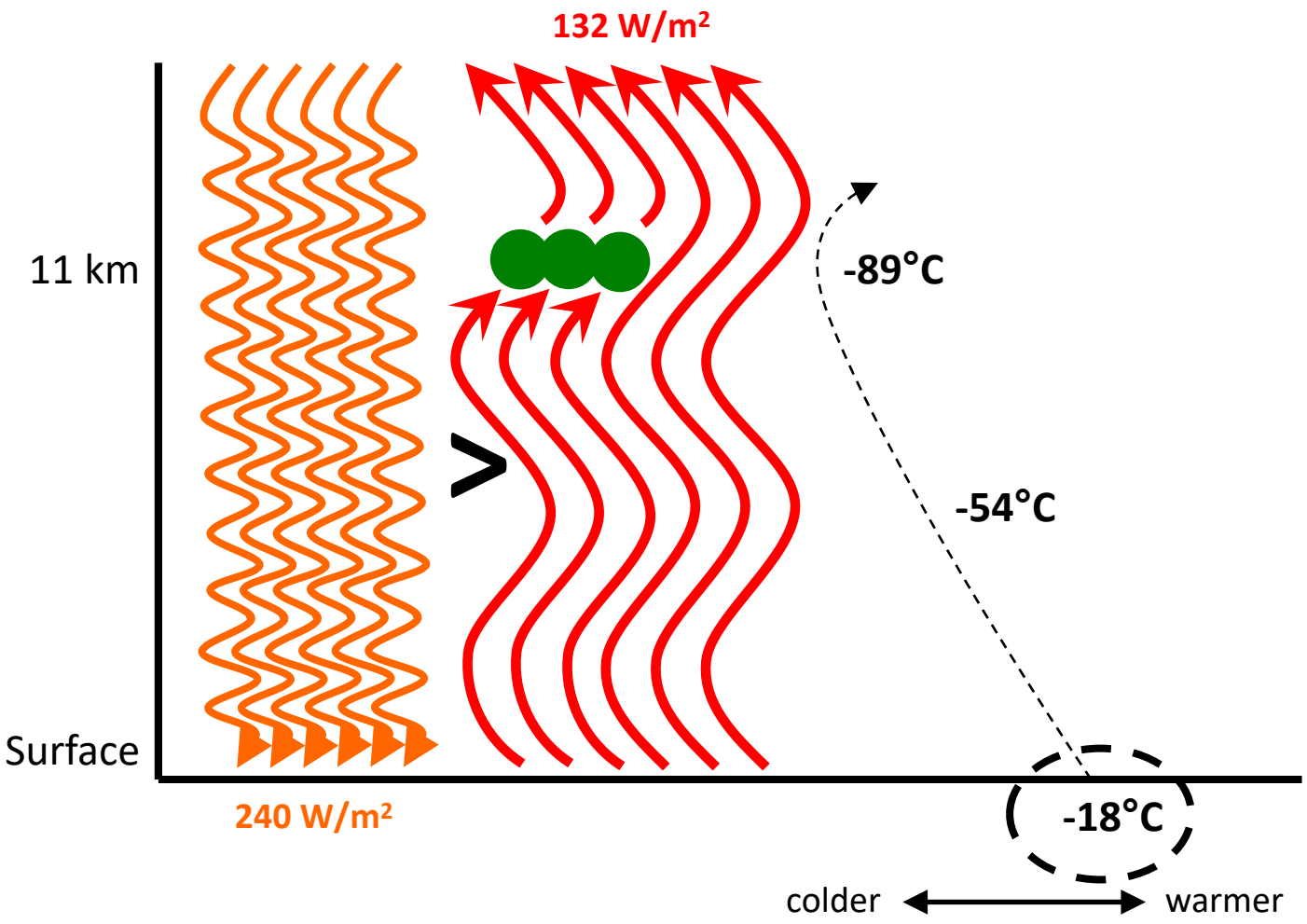
-100°C

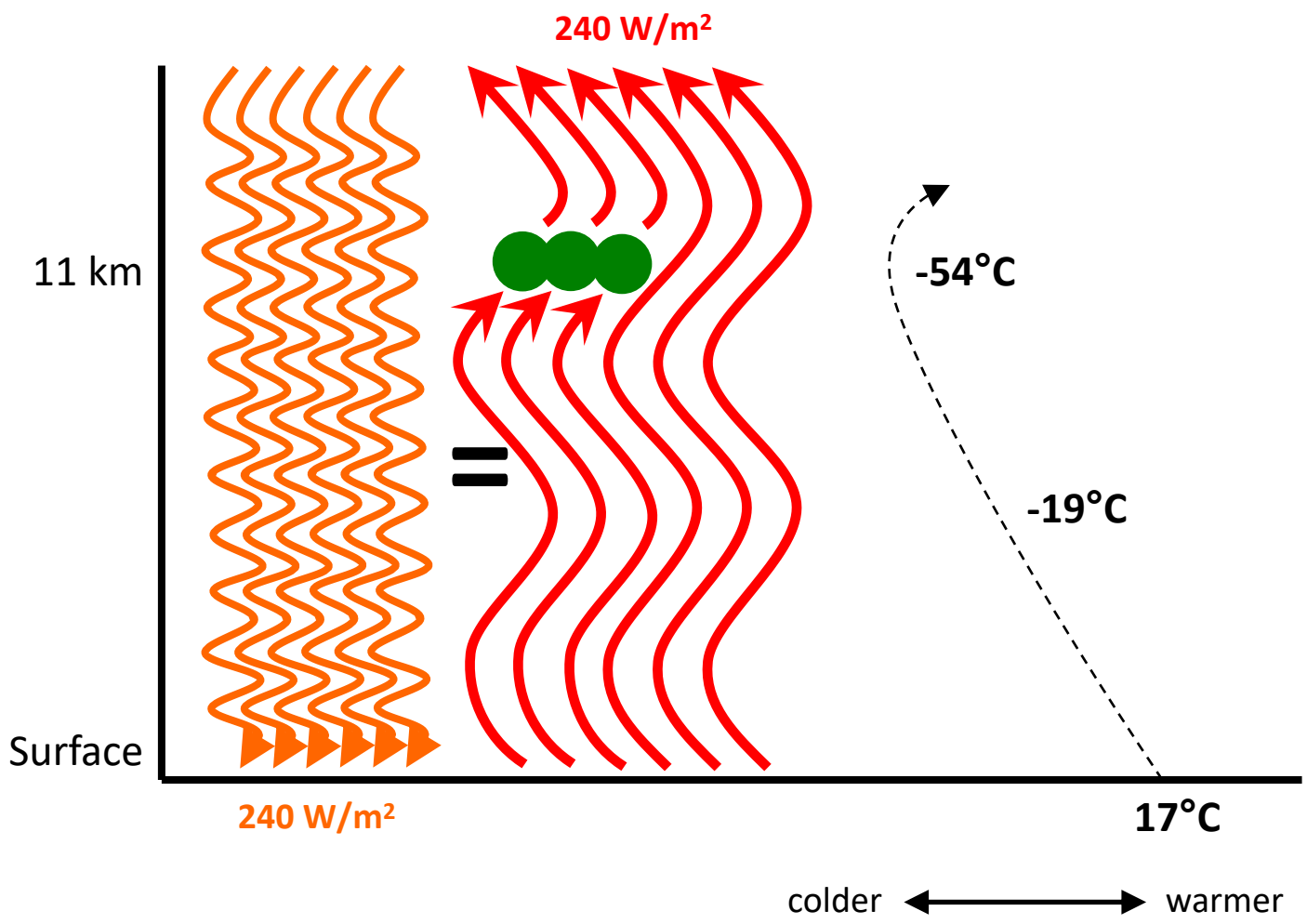


The solar radiation incident upon the top of the atmosphere is 342 W/m2. Due to reflection of solar radiation by the atmosphere (clouds, aerosols, etc.) and the surface (ice, etc.), only 240 W/m2 reaches and is absorbed by the surface. The Earth's planetary albedo (fraction reflected) is 0.3. So, 342 W/m2 * (1 - 0.3) = 240 W/m2.

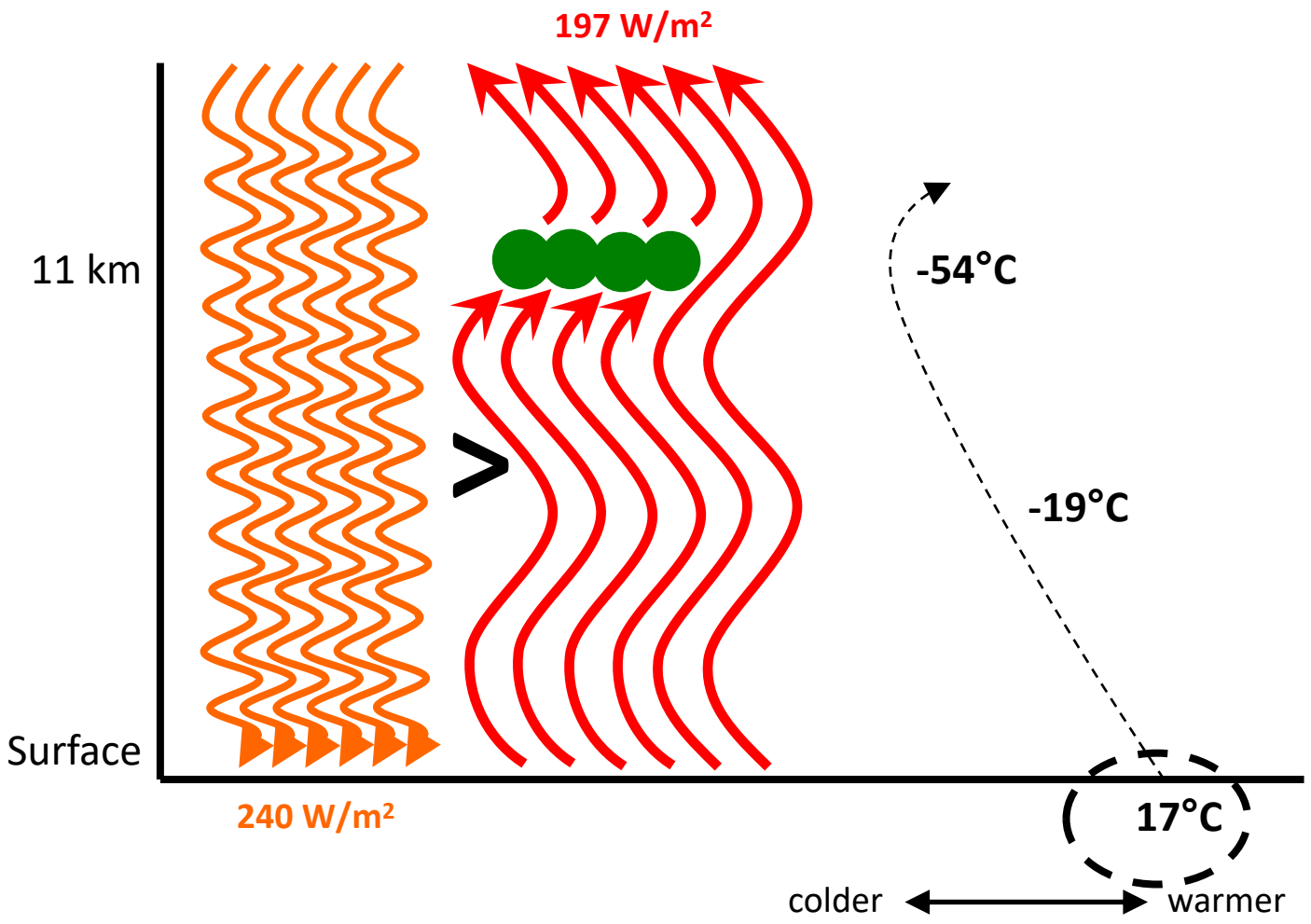

240 W/m²
11 km
Surface
240 W/m²
-18°C
colder
warmer

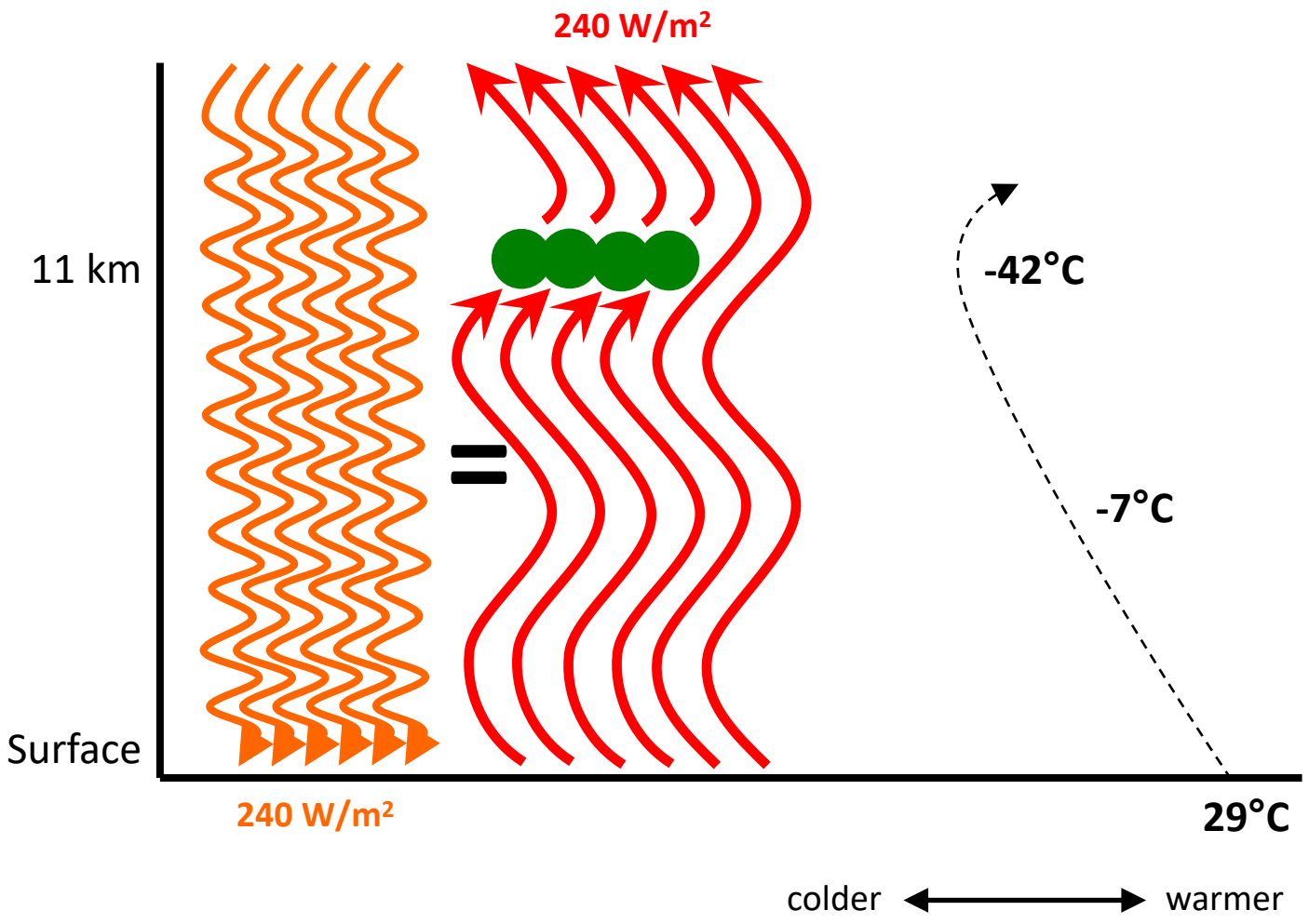

240 W/m²
11 km
-89°C
For every kilometer of altitude, temperature drops by roughly 6.5°C.
-54°C
Surface
240 W/m²
-18°C
colder
warmer

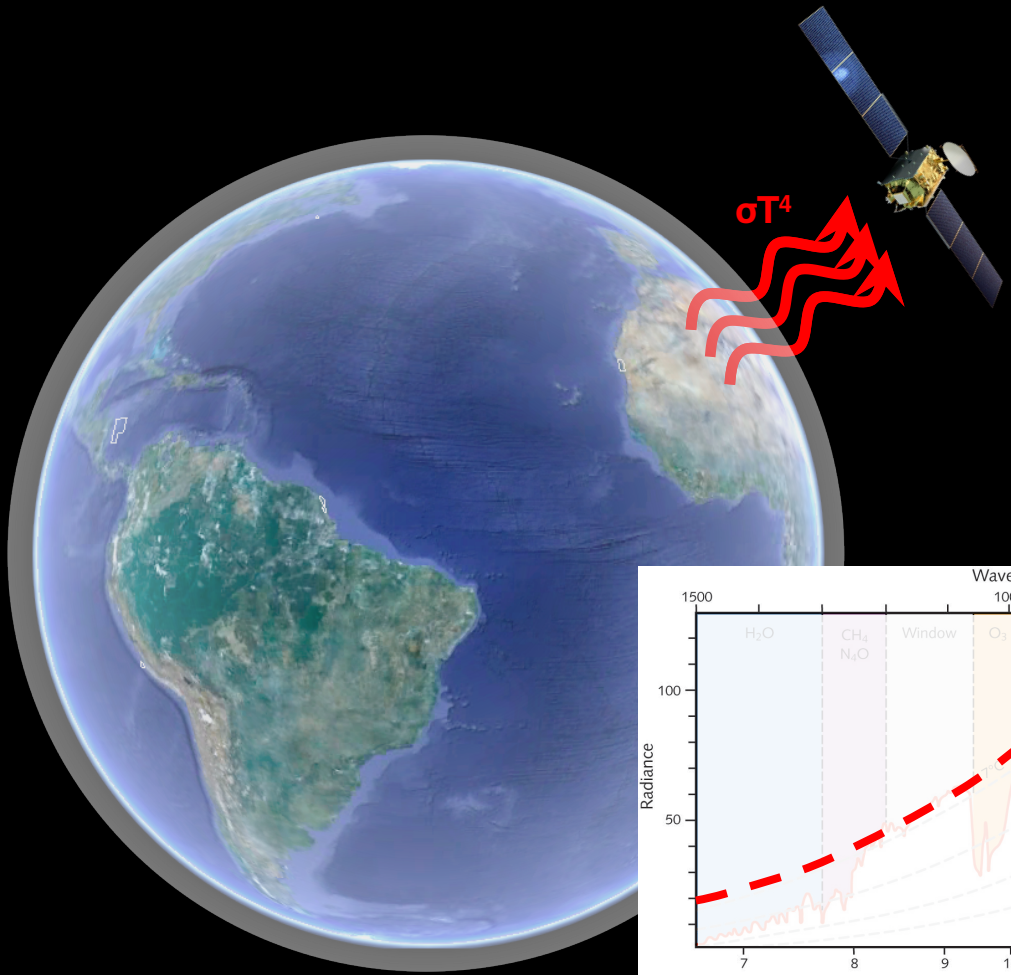

132 W/m²
11 km
-89°C
-54°C
Surface
240 W/m²
-18°C
colder
warmer



The average surface temperature of the Earth is actually 14-15°C (IPCC AR4 WG1 Ch. 1), but tough to get the numbers to work out exactly in this exercise.


197 W/m²
11 km
-54°C
-19°C
>
Surface
240 W/m²
17°C
colder
warmer


240 W/m²
11 km
Surface
240 W/m²
-42°C
-7°C
29°C
colder
warmer



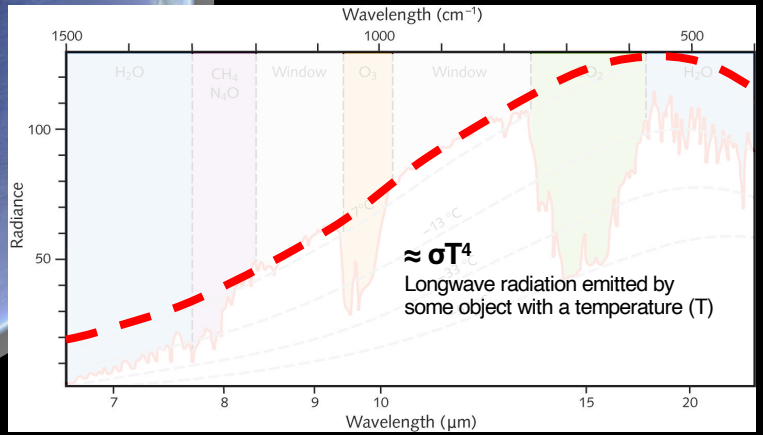
Stefan-Boltzmann's Law: The *total* radiation emitted by an object is proportional to its temperature to the 4th power (T^4).

Plank's Law: An object with a temperature T will emit different amounts of radiation at different *wavelengths*.

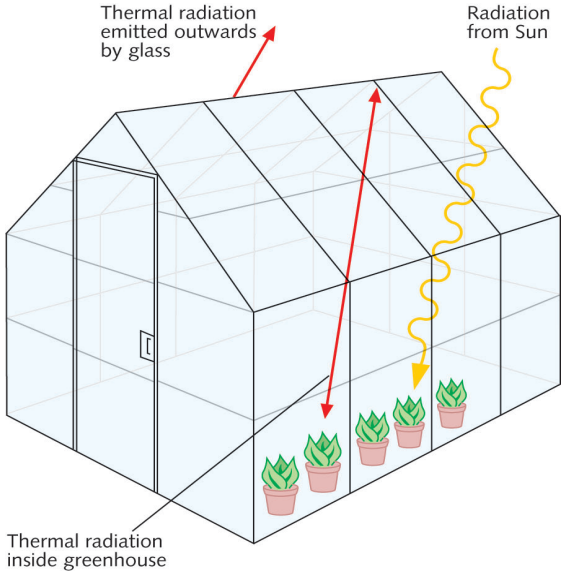
Wein's Law: Warmer objects have a peak in the emitted radiation at a shorter wavelength.

Beer's Law: How much radiation a substance absorbs depends on the substance's properties (e.g., molecular structure) and the *concentration* of the substance.

Kirchhoff's Law: Good absorbers are good emitters.



Not just theory. We have empirical data, too.



Recent observational studies have unambiguously detected the fingerprints of radiative forcing in measurements of:

- *Decreasing* trend of longwave radiation escaping Earth
- *Increasing* trend of longwave radiation hitting the surface

Increases in greenhouse forcing inferred from the outgoing longwave radiation spectra of the Earth in 1970 and 1997

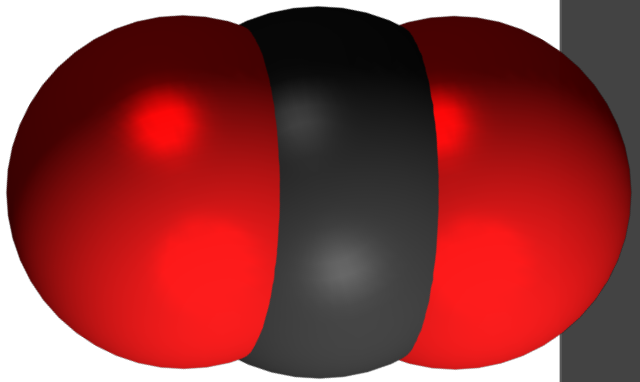
John E. Harries, Helen E. Brindley, Pretty J. Sagoo & Richard J. Bantges

Observational determination of surface radiative forcing by CO_2 from 2000 to 2010

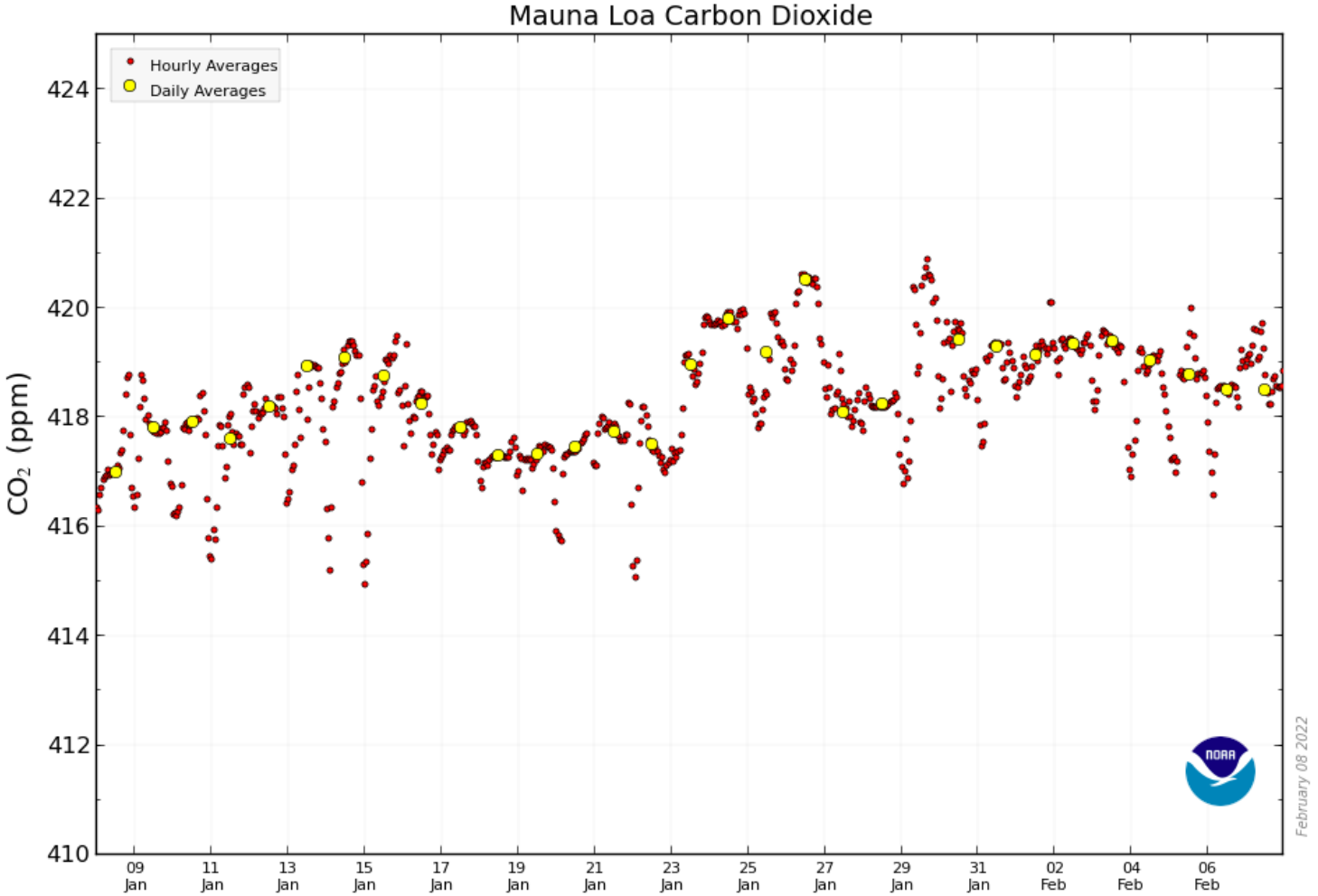
D. R. Feldman[1], W. D. Collins[1,2], P. J. Gero[3], M. S. Torn[1,4], E. J. Mlawer[5] & T. R. Shippert[6]

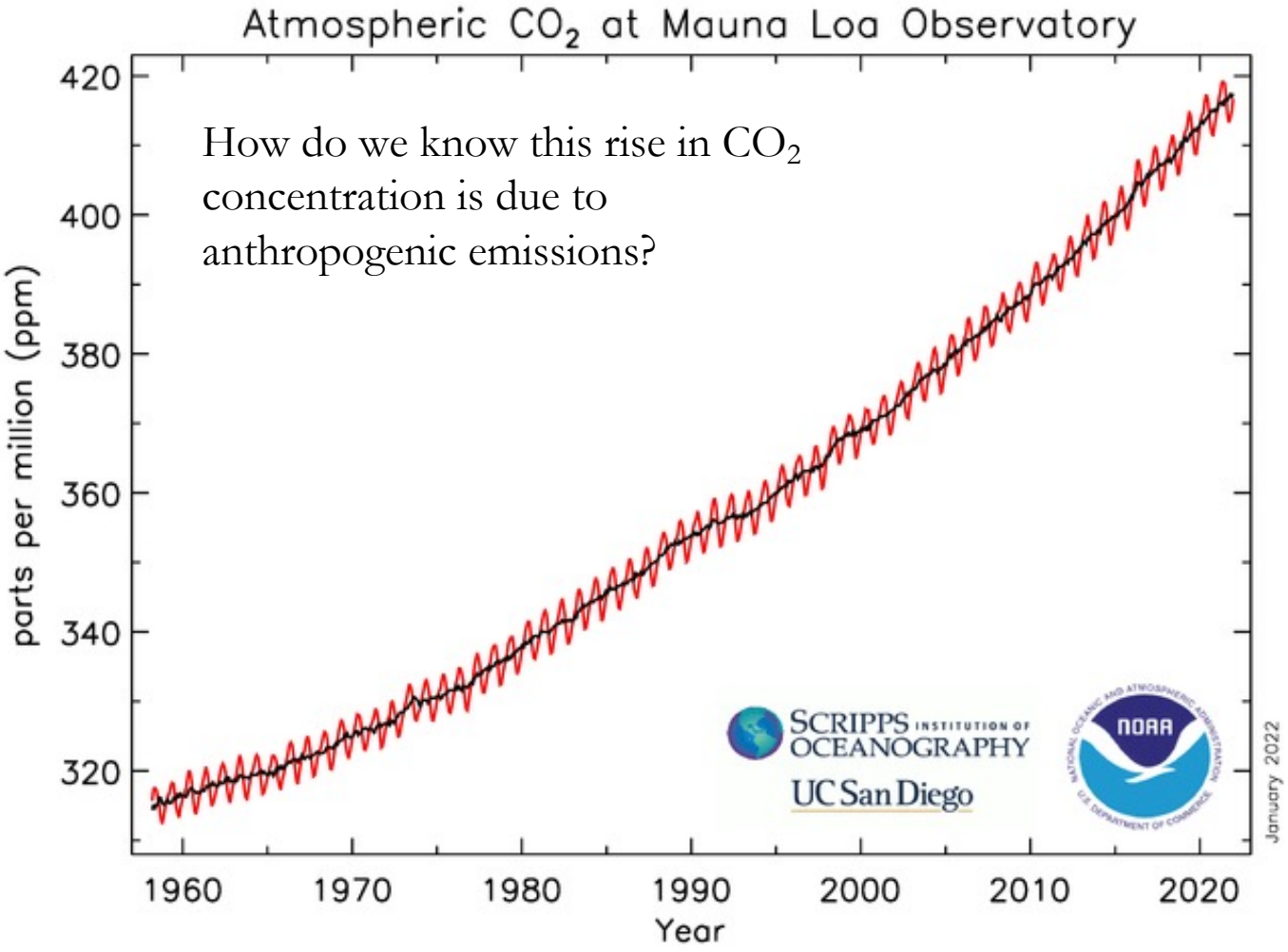
Describe the measurement and evidence base of *climate drivers.*

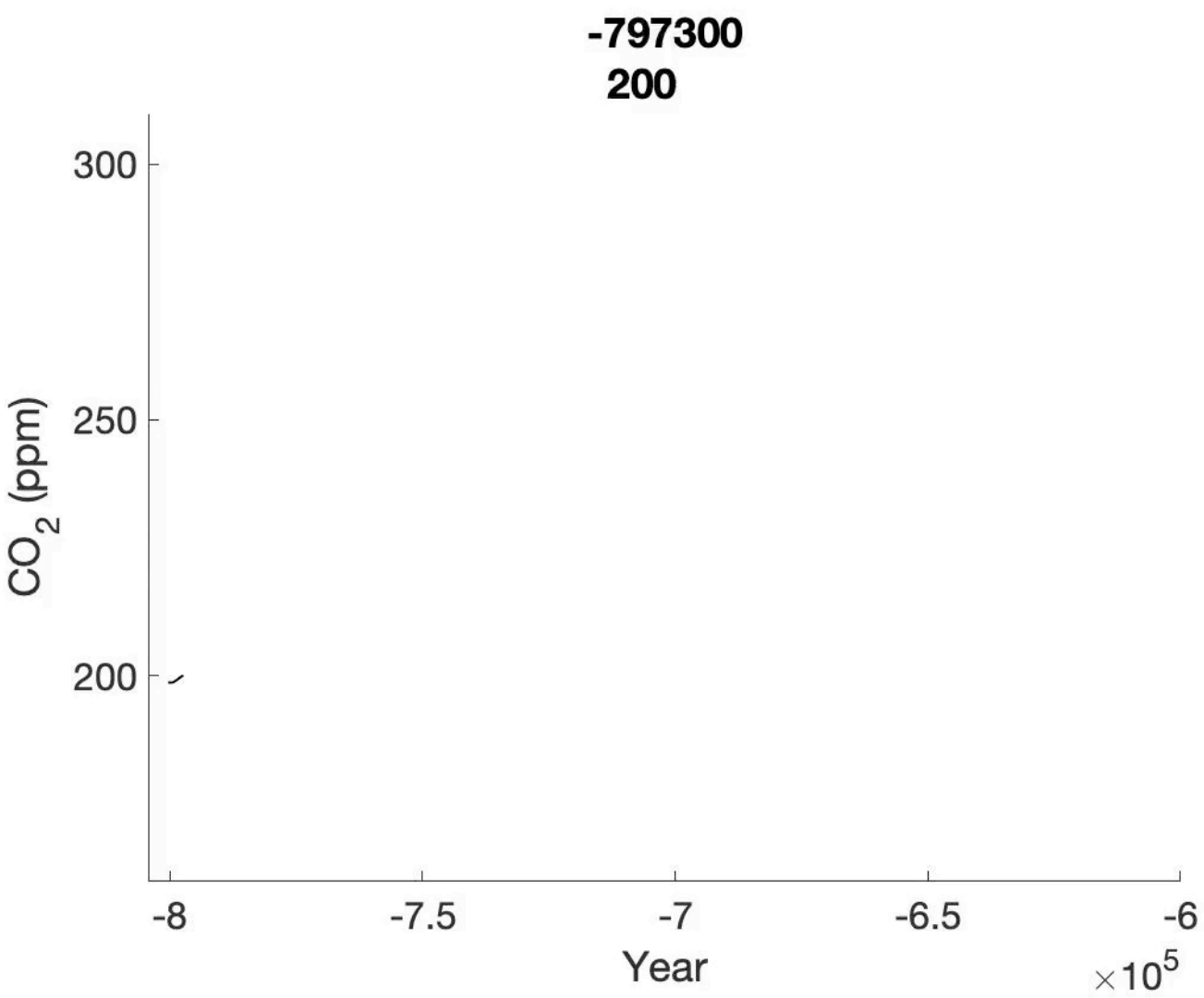
- We know *that* greenhouse gases are rising.
- We know *why* they are rising.
- We are also measuring the expected *outcomes* in real time.



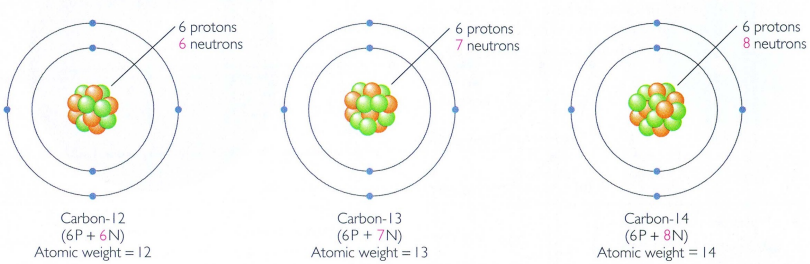
The NOAA Mauna Loa Observatory
Measuring carbon dioxide since 1958


Mauna Loa Carbon Dioxide
Hourly Averages
Daily Averages
CO2 (ppm)
424
422
420
418
416
414
412
410
09 Jan
11 Jan
13 Jan
15 Jan
17 Jan
19 Jan
21 Jan
23 Jan
25 Jan
27 Jan
29 Jan
31 Jan
02 Feb
04 Feb
06 Feb
NOAA
February 08 2022


Atmospheric CO_2 at Mauna Loa Observatory
How do we know this rise in CO_2 concentration is due to anthropogenic emissions?
parts per million (ppm)
420
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
Year
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego
NOAA
January 2022

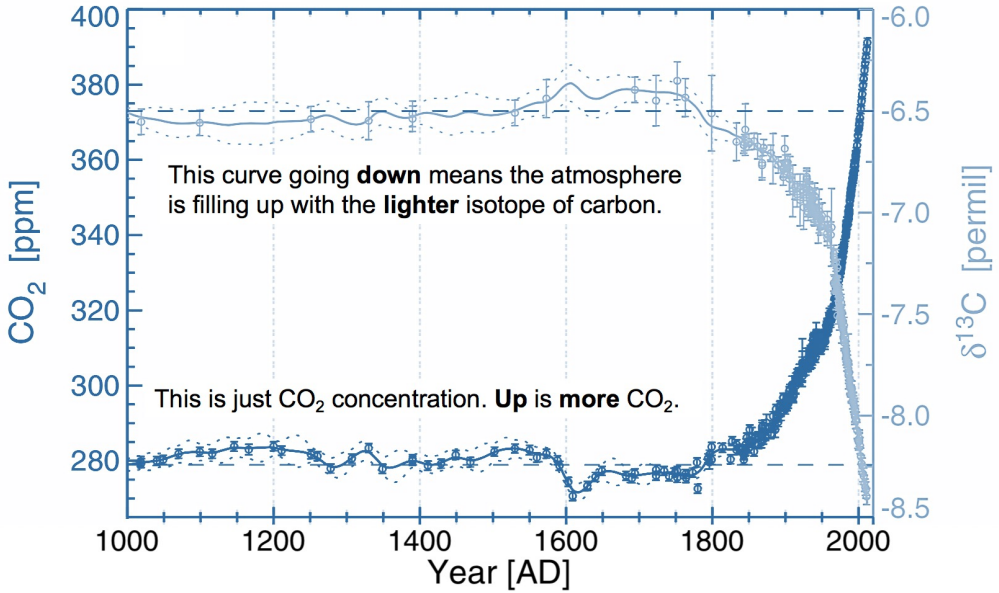

-797300
200
300
250
200
CO_2 (ppm)
-8
-7.5
-7
-6.5
-6
Year
$\times 10^5$

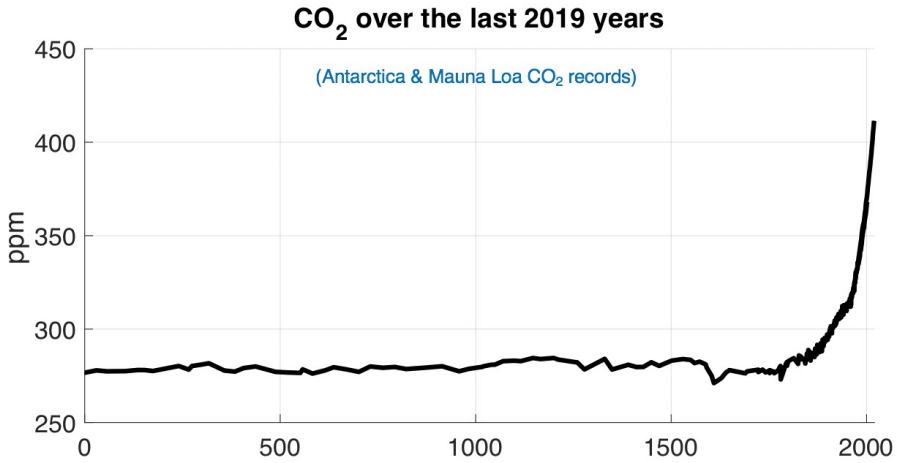
Chemistry tells us the rising CO_2 is due to fossil fuel burning.

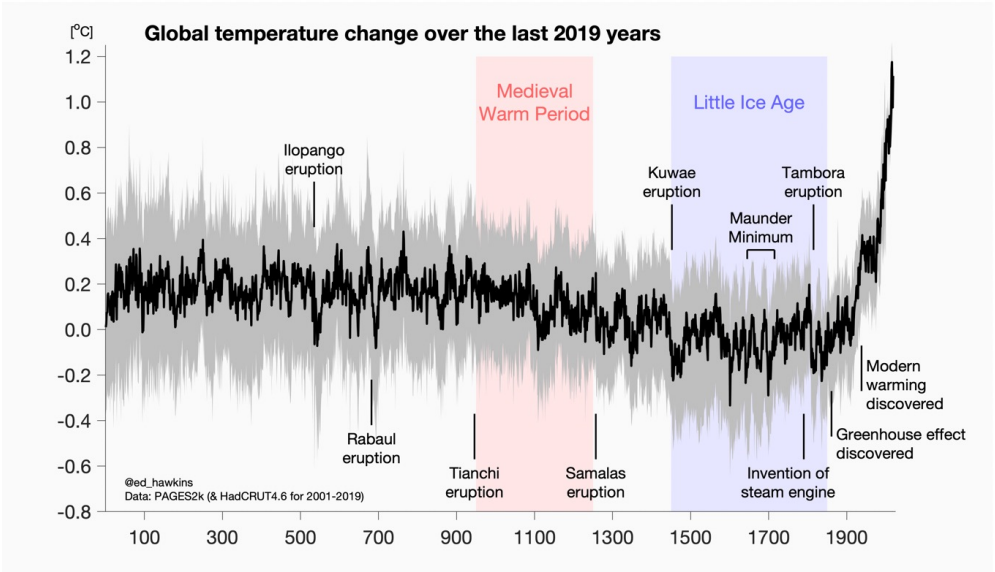


CO_2 from fossil fuels has a distinct isotopic fingerprint.

- Fossil fuels are buried, decayed plant matter.
- Plants breathe CO_2 but prefer the lighter ^{12}C.
- CO_2 emitted from combusting fossil fuels increases the amount of ^{12}C in the atmosphere relative to ^{13}C.
- The $^{13}C/^{12}C$ ratio started going *down* precisely when CO_2 started going *up*.

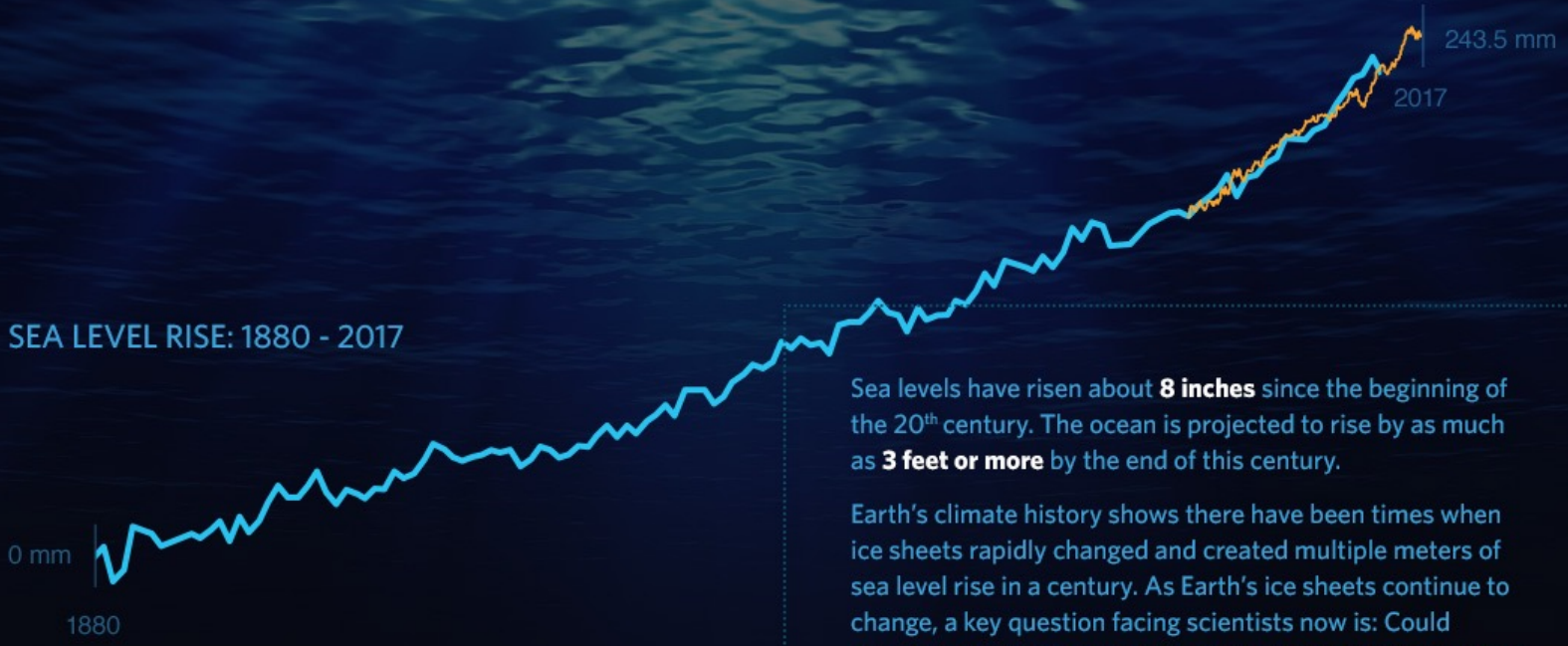



CO_2 over the last 2019 years
(Antarctica & Mauna Loa CO_2 records)
ppm
450
400
350
300
250
0
500
1000
1500
2000


Global temperature change over the last 2019 years
[°C]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
Medieval Warm Period
Little Ice Age
Ilopango eruption
Kuwae eruption
Tambora eruption
Maunder Minimum
Modern warming discovered
Greenhouse effect discovered
Rabaul eruption
Tianchi eruption
Samalas eruption
Invention of steam engine
@ed_hawkins
Data: PAGES2k (& HadCRUT4.6 for 2001-2019)
100
300
500
700
900
1100
1300
1500
1700
1900

AS OUR OCEAN WARMS, SEA LEVEL RISES

We know seas are rising and we know why. The urgent questions are by how much and how quickly.



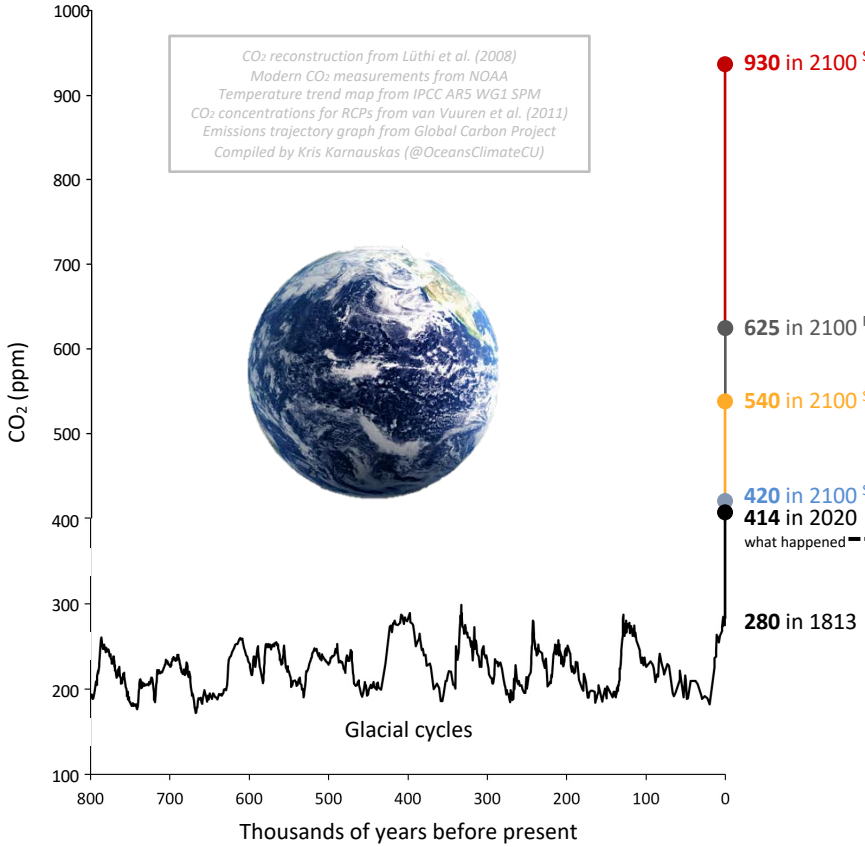
Sea levels have risen about **8 inches** since the beginning of the 20th century. The ocean is projected to rise by as much as **3 feet or more** by the end of this century.

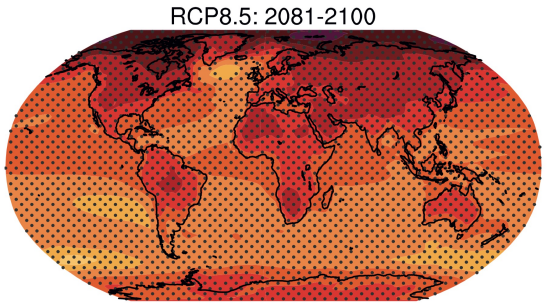
Earth's climate history shows there have been times when ice sheets rapidly changed and created multiple meters of sea level rise in a century. As Earth's ice sheets continue to change, a key question facing scientists now is: Could human-caused global warming be pushing us toward one of those times?

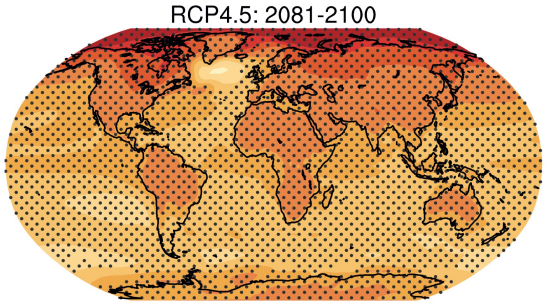
Explain the *societal dimensions of climate drivers.*

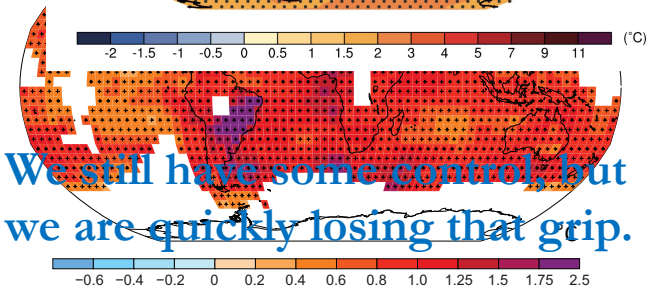
- Societal dimensions of “climate drivers” (greenhouse gas emissions) include population, wealth/economic growth, energy policy, environmental attitudes, nationalism/regional relations, in addition to energy technology and more.
- Shared socioeconomic pathways (SSPs) define five possible futures.
- Those five SSPs have five very different outcomes in terms of climate change.

We are conducting a big, accidental **science experiment** with our planet!









We still have some control, but we are quickly losing that grip.

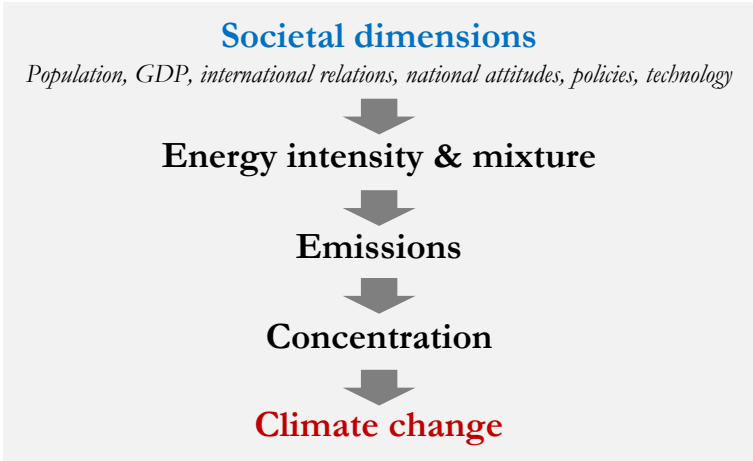
Current methodology: **Shared Socioeconomic Pathways (SSPs)**

Five different ways in which the world might evolve in the absence of climate policy and how different levels of climate change mitigation could be achieved when the mitigation targets of RCPs are combined with the SSPs

SSP1 **Sustainability – Taking the Green Road (Low challenges to mitigation and adaptation)**
The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity.

SSP3 **Regional Rivalry – A Rocky Road (High challenges to mitigation and adaptation)**
A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. Policies shift over time to become increasingly oriented toward national and regional security issues. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialized and high in developing countries. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions.

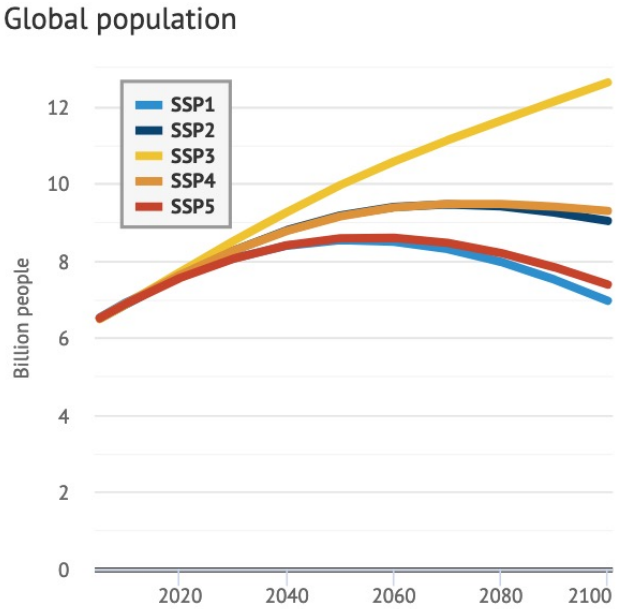
SSP5 **Fossil-fueled Development – Taking the Highway (High challenges to mitigation, low challenges to adaptation)**
This world places increasing faith in competitive markets, innovation and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Global markets are increasingly integrated. There are also strong investments in health, education, and institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the 21st century. Local environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary.

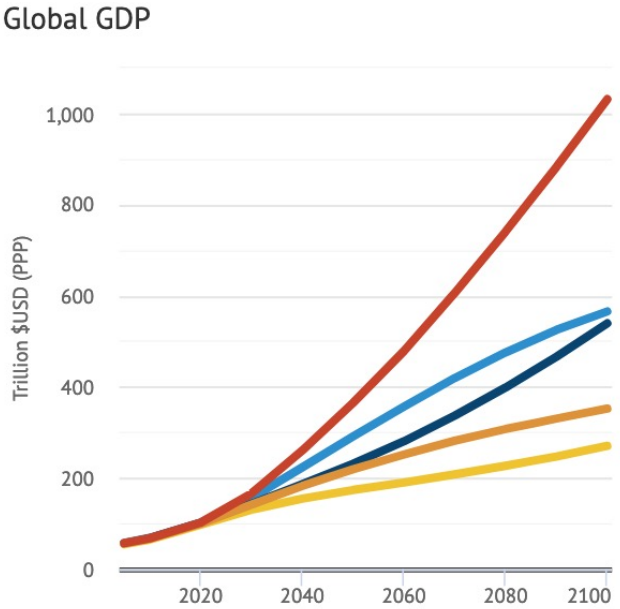


Great explainer on SSPs: https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change

Current methodology: **Shared Socioeconomic Pathways (SSPs)**

Five different ways in which the world might evolve in the absence of climate policy and how different levels of climate change mitigation could be achieved when the mitigation targets of RCPs are combined with the SSPs





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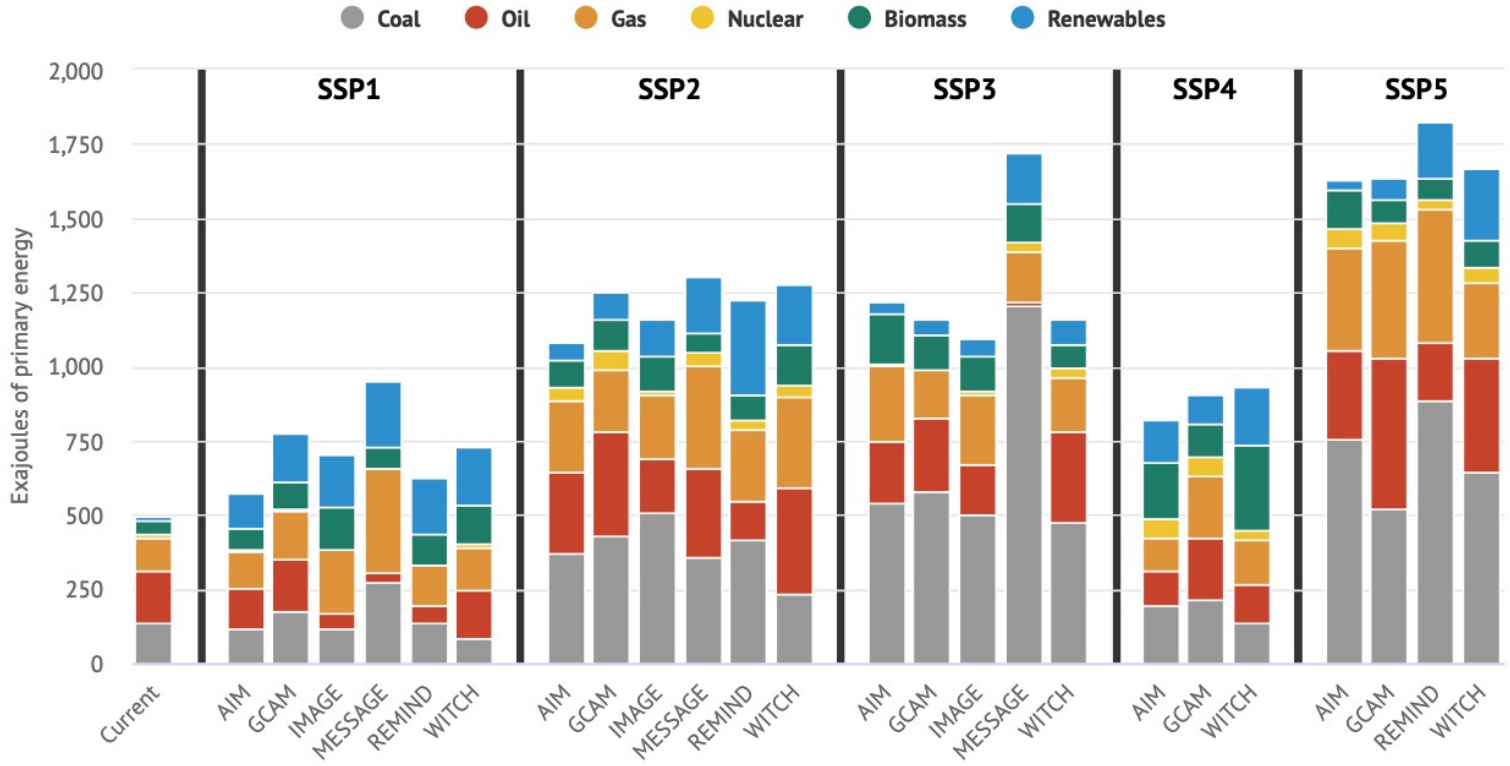

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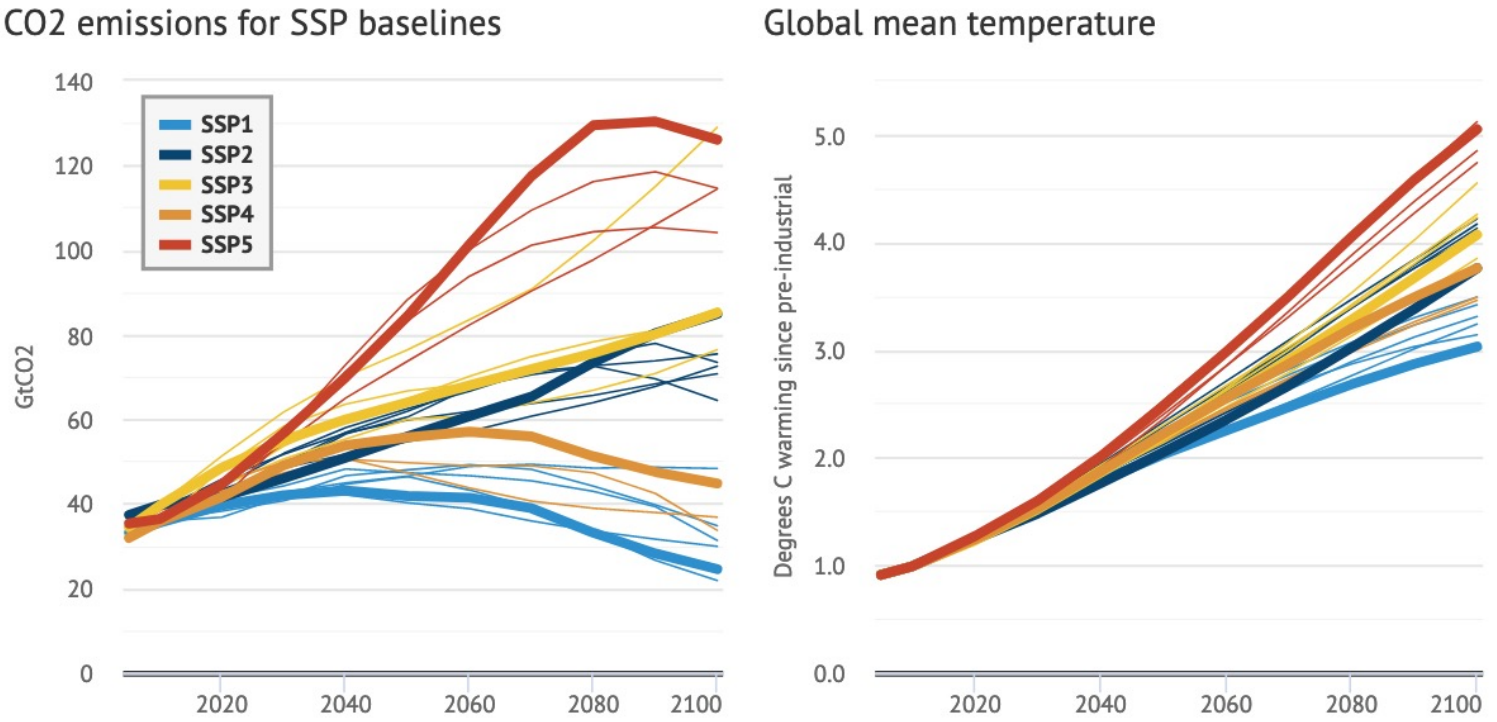

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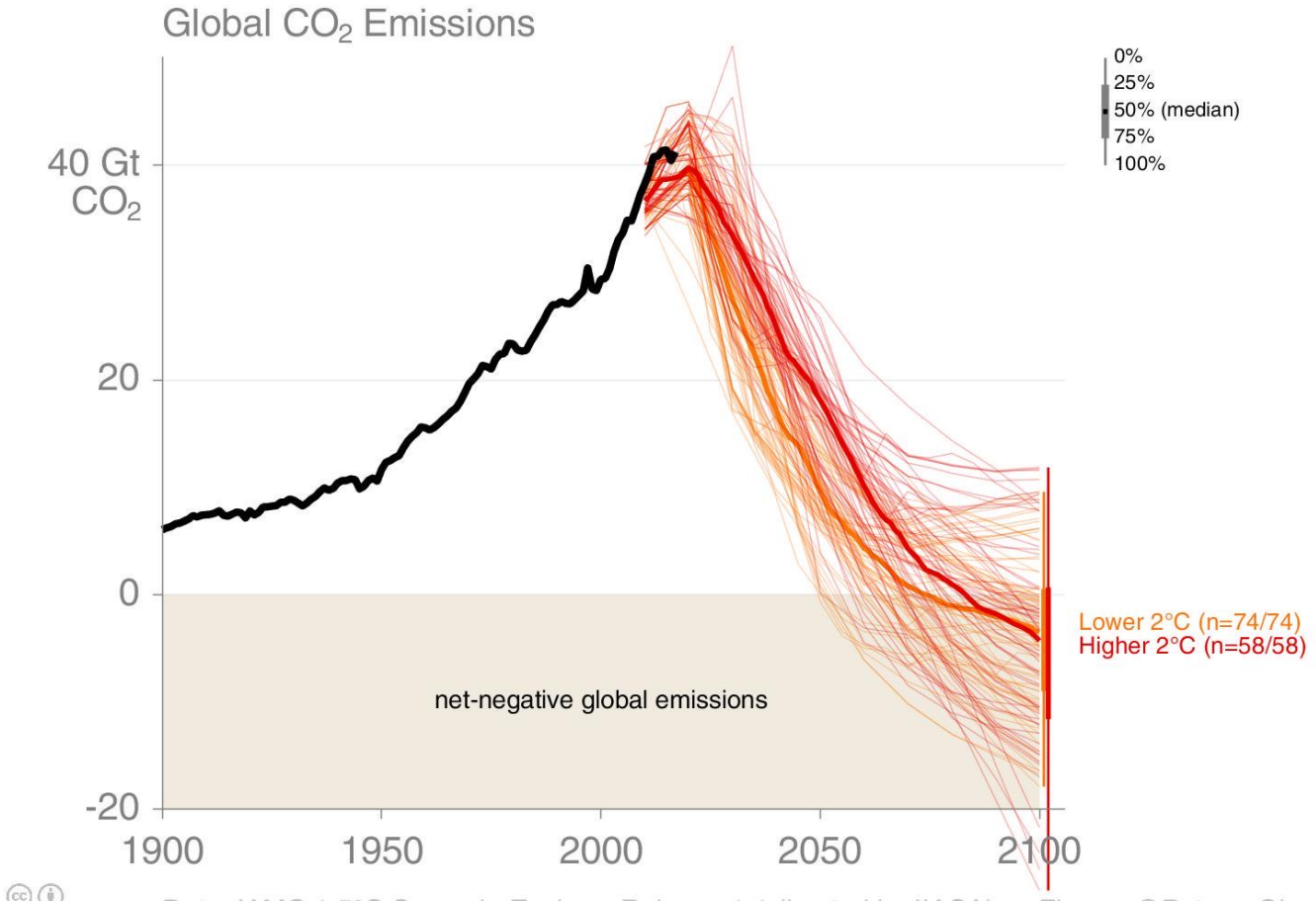
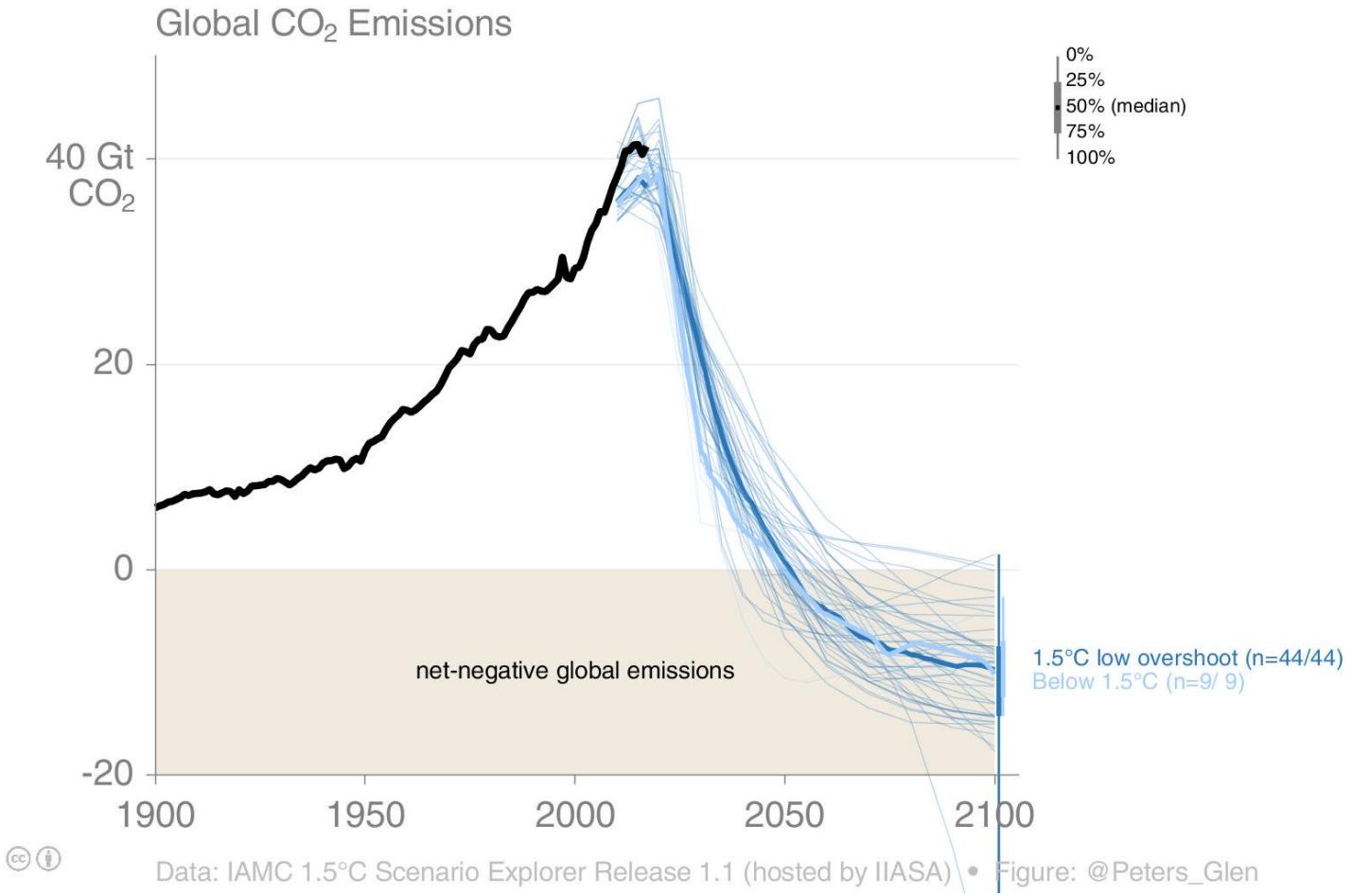
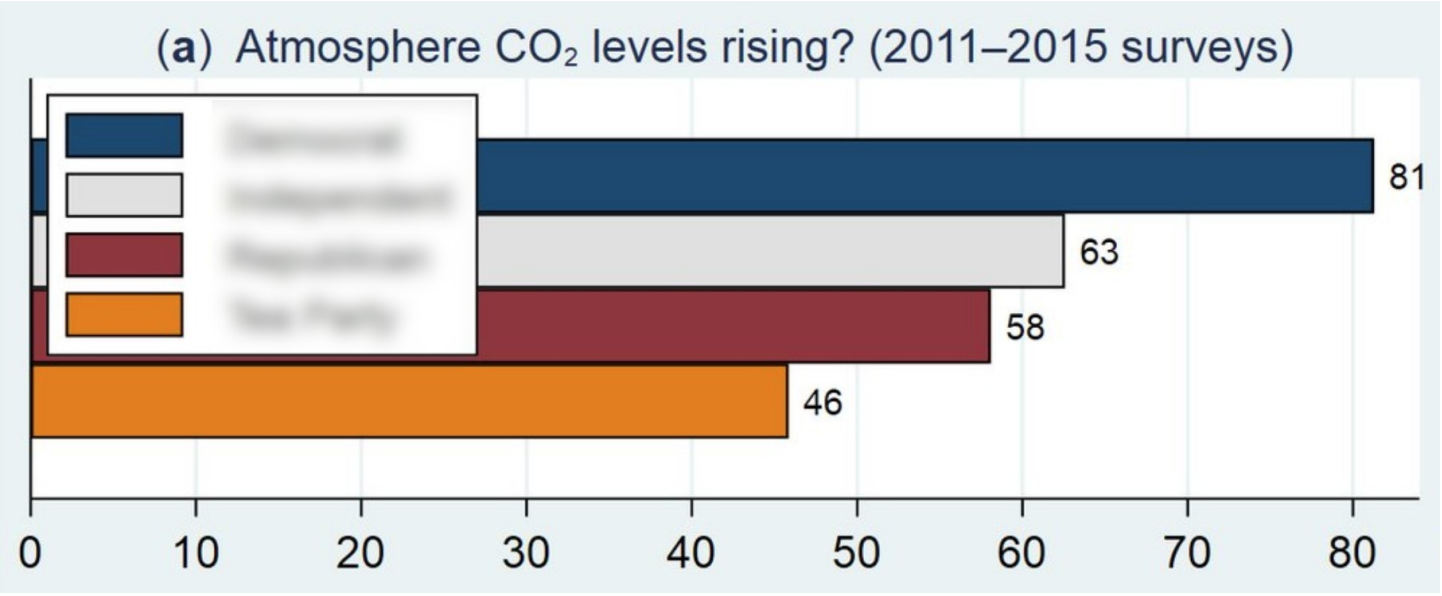

Global CO_2 Emissions
40 Gt CO_2
20
0
-20
1900
1950
2000
2050
2100
0%
25%
50% (median)
75%
100%
net-negative global emissions
Lower 2°C (n=74/74)
Higher 2°C (n=58/58)
Data: IAMC 1.5°C Scenario Explorer Release 1.1 (hosted by IIASA) • Figure: @Peters_Glen


Global CO_2 Emissions
40 Gt CO_2
20
0
-20
1900
1950
2000
2050
2100
net-negative global emissions
0%
25%
50% (median)
75%
100%
1.5°C low overshoot (n=44/44)
Below 1.5°C (n=9/ 9)
Data: IAMC 1.5°C Scenario Explorer Release 1.1 (hosted by IIASA) • Figure: @Peters_Glen

Communicate the degree of *scientific consensus* on climate change and become familiar with the IPCC and other core resources.

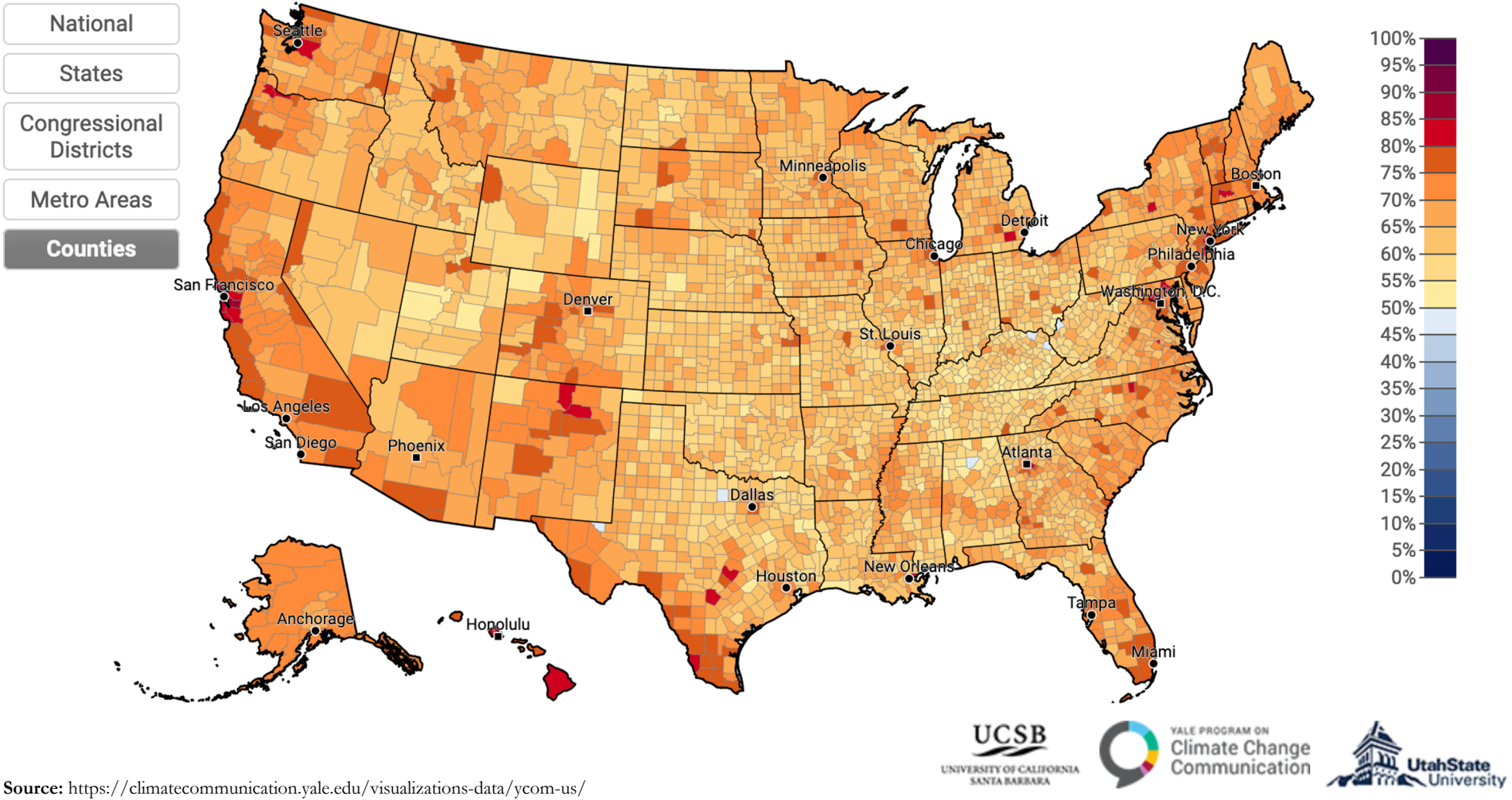
- The *scientific* consensus is overwhelming (>99% on the most important question).
- The *public* "consensus" is not impressive, and is highly correlated with political views (party affiliation, in the U.S.), but perceptions may be slowly shifting.
- The Intergovernmental Panel on Climate Change (IPCC) summarizes the state of the science every ~6 years.
- One of the major outcomes of the IPCC Reports is an assessment of uncertainty (both qualitative and general) in past *and* future climate change.

Views on even the most basic and **well-established facts** about climate change are polarized by political party.



Source: Larry Hamilton, Department of Sociology, and Carsey School of Public Policy, University of New Hampshire

Estimated % of adults who think: **global warming is happening** (72%), 2020



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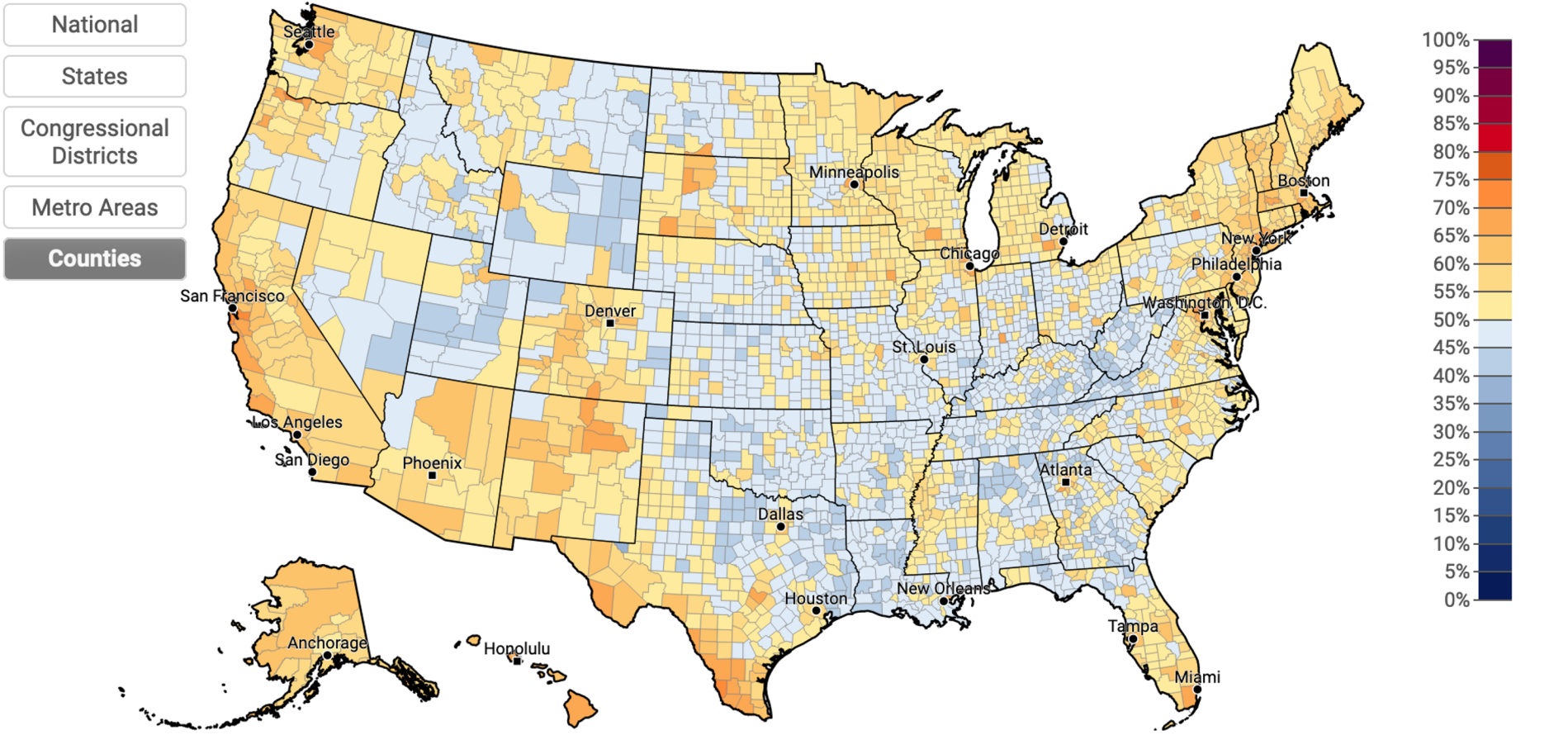
YALE PROGRAM ON Climate Change Communication

UtahState University

Source: https://climatecommunication.yale.edu/visualizations-data/ycom-us/

Estimated % of adults who think: **global warming is mostly caused by human activities** (57%), 2020



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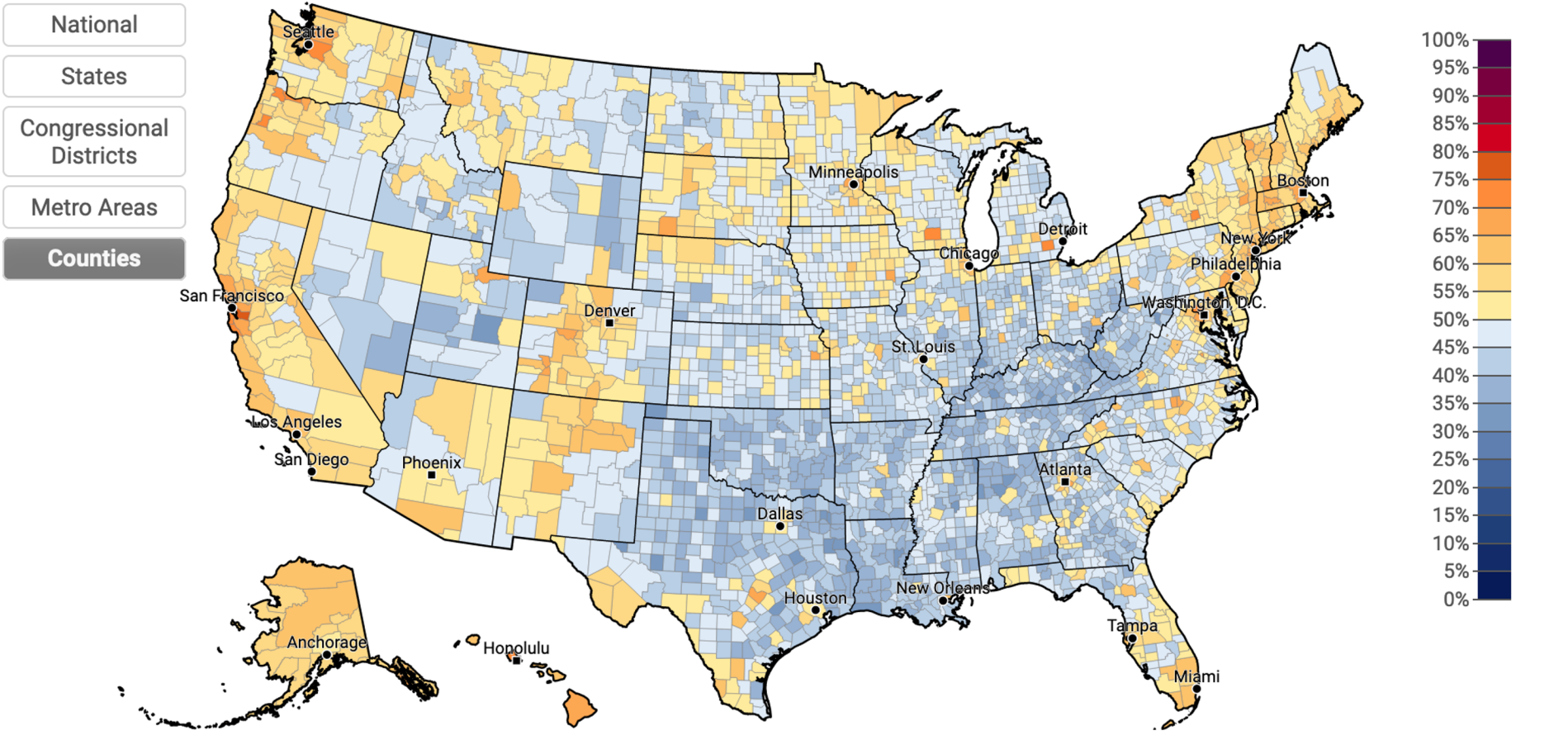
YALE PROGRAM ON Climate Change Communication

UtahState University

Source: https://climatecommunication.yale.edu/visualizations-data/ycom-us/

Estimated % of adults who believe: **most scientists think global warming is happening** (55%), 2020



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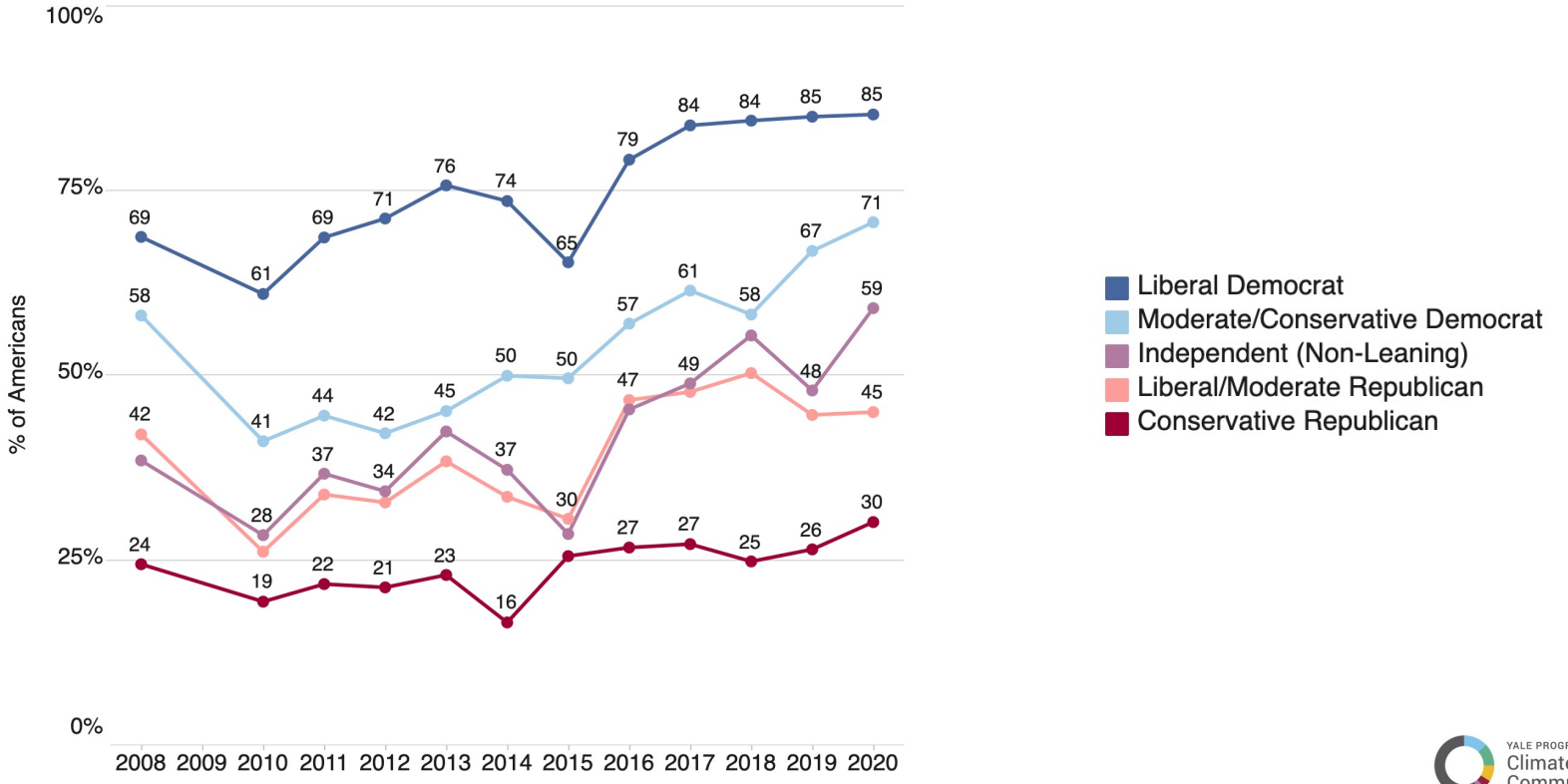
Estimated % of adults who believe: **most scientists think global warming is happening** (55%), 2020



YALE PROGRAM ON Climate Change Communication

GEORGE MASON UNIVERSITY CENTER *for* CLIMATE CHANGE COMMUNICATION

Source: https://climatecommunication.yale.edu/visualizations-data/ycom-us/

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ENVIRONMENTAL RESEARCH
LETTERS

LETTER

Greater than 99% consensus on human caused climate change in the peer-reviewed scientific literature

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Keywords: global warming, climate change, scientific consensus

Supplementary material for this article is available online

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Abstract

While controls over the Earth's climate system have undergone rigorous hypothesis-testing since the 1800s, questions over the scientific consensus of the role of human activities in modern climate change continue to arise in public settings. We update previous efforts to quantify the scientific consensus on climate change by searching the recent literature for papers sceptical of anthropogenic-caused global warming. From a dataset of 88125 climate-related papers published since 2012, when this question was last addressed comprehensively, we examine a randomized subset of 3000 such publications. We also use a second sample-weighted approach that was specifically biased with keywords to help identify any sceptical peer-reviewed papers in the whole dataset. We identify four sceptical papers out of the sub-set of 3000, as evidenced by abstracts that were rated as implicitly or explicitly sceptical of human-caused global warming. In our sample utilizing pre-identified sceptical keywords we found 28 papers that were implicitly or explicitly sceptical. We conclude with high statistical confidence that the scientific consensus on human-caused contemporary climate change—expressed as a proportion of the total publications—exceeds 99% in the peer reviewed scientific literature.

1. Introduction

The extent of the scientific consensus on human-caused climate change is of great interest to society. If there remains substantial genuine scientific doubt of the partisan divide in American politics on whether observed increases in the planet's temperature since the Industrial Revolution are primarily caused by humans [1]. Among elected U.S. politicians the divide is similarly stark: according to the Center for Amer-

"Our results confirm, as has been found in numerous other previous studies of this question, that there is no significant scientific debate among experts about whether or not climate change is human-caused. This issue has been comprehensively settled, and the reality of ACC is no more in contention among scientists than is plate tectonics or evolution."

"The tiny number of papers that have been published during our time period which disagree with this overwhelming scientific consensus have had no discernible impact, presumably because they do not provide any convincing evidence…"

Public engagement is critical.

And…

Credentialed climate scientists who do engage tend to have very little patience for hyperbole and exaggerated claims.

As scientists, we are well aware of the misinformation campaigns, but misinformation needs to be avoided on both sides, and regardless of the intentions.

You may be surprised how quickly things like this get jumped on!

Writer/director in LA (*Don't Look Up*). 1M followers on Twitter.

Climate scientist (Ph.D.) at UK Met Office & Exeter University. IPCC lead author.

Climate scientist (Ph.D.) at UCLA, NCAR & Nature Conservancy.

American Association for the Advancement of Science

"Based on well-established evidence, about 97% of climate scientists have concluded that human-caused climate change is happening." (2014)[3]

American Chemical Society

"The Earth's climate is changing in response to increasing concentrations of greenhouse gases (GHGs) and particulate matter in the atmosphere, largely as the result of human activities." (2016-2019)[4]

American Geophysical Union

"Based on extensive scientific evidence, it is extremely likely that human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming since the mid-20th century. There is no alterative explanation supported by convincing evidence." (2019)[5]

American Medical Association

"Our AMA ... supports the findings of the Intergovernmental Panel on Climate Change's fourth assessment report and concurs with the scientific consensus that the Earth is undergoing adverse global climate change and that anthropogenic contributions are significant." (2019)[6]

American Meteorological Society

"Research has found a human influence on the climate of the past several decades ... The IPCC (2013), USGCRP (2017), and USGCRP (2018) indicate that it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-twentieth century." (2019)[7]

American Physical Society

"Earth's changing climate is a critical issue and poses the risk of significant environmental, social and economic disruptions around the globe. While natural sources of climate variability are significant, multiple lines of evidence indicate that human influences have had an increasingly dominant effect on global climate warming observed since the mid-twentieth century."

The Geological Society of America

"The Geological Society of America (GSA) concurs with assessments by the National Academies of Science (2005), the National Research Council (2011), the Intergovernmental Panel on Climate Change (IPCC, 2013) and the U.S. Global Change Research Program (Melillo et al., 2014) that global climate has warmed in response to increasing concentrations of carbon dioxide (CO2) and other greenhouse gases ...

U.S. National Academy of Sciences

"Scientists have known for some time, from multiple lines of evidence, that humans are changing Earth's climate, primarily through greenhouse gas emissions."[11]

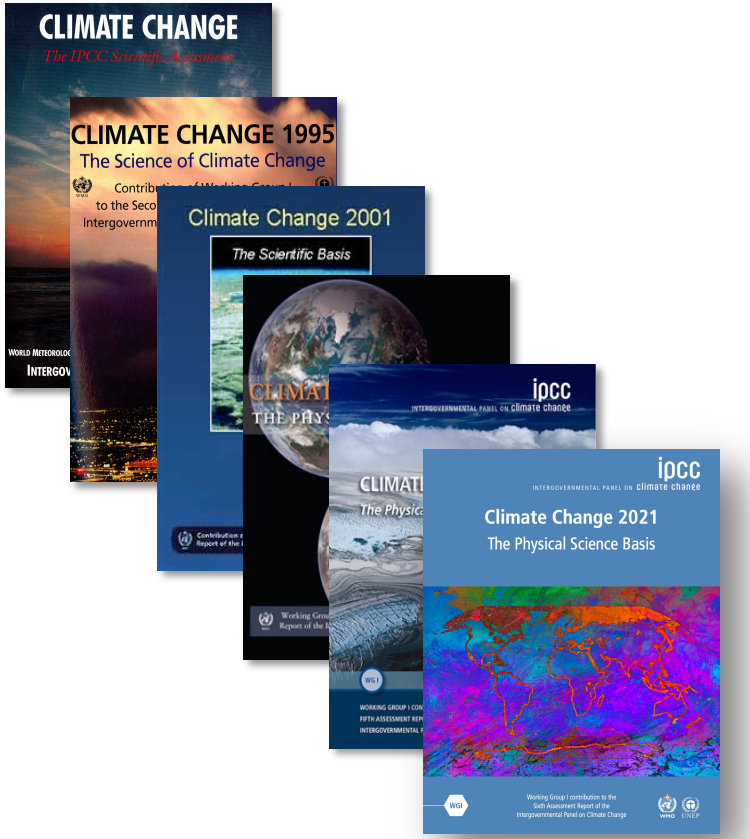
- *The IPCC was created to provide policymakers with regular scientific assessments on climate change, its implications and potential future risks, as well as to put forward adaptation and mitigation options.*

- *The IPCC does not conduct its own research [but synthesizes the existing body of peer–reviewed research including the results of the global climate modeling enterprise.]*

- *IPCC reports are neutral, policy-relevant but not policy-prescriptive.*

Intergovernmental Panel on Climate Change (IPCC) Assessment Reports (ARs)

1990	First Assessment Report (FAR)
1995	Second Assessment Report (SAR)
2001	Third Assessment Report (TAR)
2007	Fourth Assessment Report (AR4)
2013	Fifth Assessment Report (AR5)
2021	Sixth Assessment Report (AR6)



Introduction

This Summary for Policymakers (SPM) presents key findings of the Working Group I (WGI) contribution to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6)[1] on the physical science basis of climate change. The report builds upon the 2013 Working Group I contribution to the IPCC's Fifth Assessment Report (AR5) and the 2018–2019 IPCC Special Reports[2] of the AR6 cycle and incorporates subsequent new evidence from climate science.[3]

This SPM provides a high-level summary of the understanding of the current state of the climate, including how it is changing and the role of human influence, the state of knowledge about possible climate futures, climate information relevant to regions and sectors, and limiting human-induced climate change.

Based on scientific understanding, key findings can be formulated as statements of fact or associated with an assessed level of confidence indicated using the IPCC calibrated language.[4]

The scientific basis for each key finding is found in chapter sections of the main Report and in the integrated synthesis presented in the Technical Summary (hereafter TS), and is indicated in curly brackets. The AR6 WGI Interactive Atlas facilitates exploration of these key synthesis findings, and supporting climate change information, across the WGI reference regions.[5]

A. The Current State of the Climate

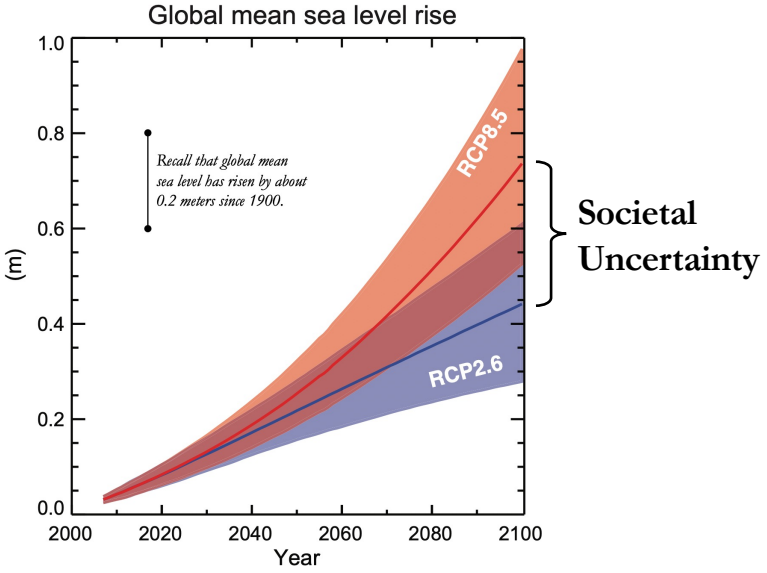
Since AR5, improvements in observationally based estimates and information from paleoclimate archives provide a comprehensive view of each component of the climate system and its changes to date. New climate model simulations, new analyses, and methods combining multiple lines of evidence lead to improved understanding of human influence on a wider range of climate variables, including weather and climate extremes. The time periods considered throughout this section depend upon the availability of observational products, paleoclimate archives and peer-reviewed studies.

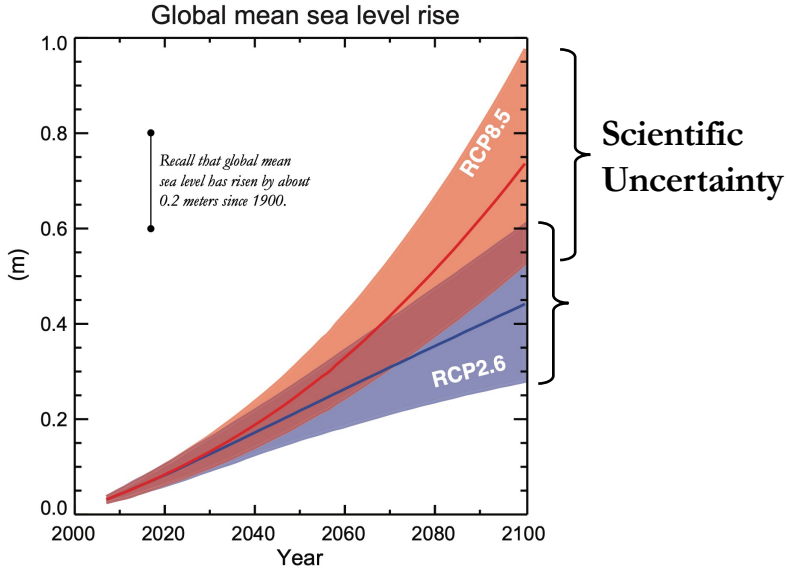
A.1 **It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.**
{2.2, 2.3, Cross-Chapter Box 2.3, 3.3, 3.4, 3.5, 3.6, 3.8, 5.2, 5.3, 6.4, 7.3, 8.3, 9.2, 9.3, 9.5, 9.6, Cross-Chapter Box 9.1} (Figure SPM.1, Figure SPM.2)

A.1.1 Observed increases in well-mixed greenhouse gas (GHG) concentrations since around 1750 are unequivocally caused by human activities. Since 2011 (measurements reported in AR5), concentrations have continued to increase in the atmosphere, reaching annual averages of 410 parts per million (ppm) for carbon dioxide (CO_2), 1866 parts per billion (ppb) for methane (CH_4), and 332 ppb for nitrous oxide (N_2O) in 2019.[6] Land and ocean have taken up a near-constant proportion (globally about 56% per year) of CO_2 emissions from human activities over the past six decades, with regional differences (*high confidence*).[7]
{2.2, 5.2, 7.3, TS.2.2, Box TS.5}

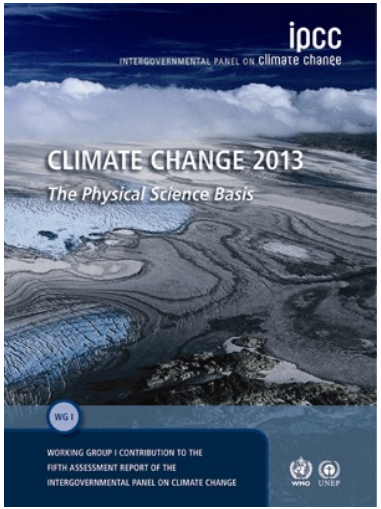
Uncertainties in *projected* rates of sea level rise

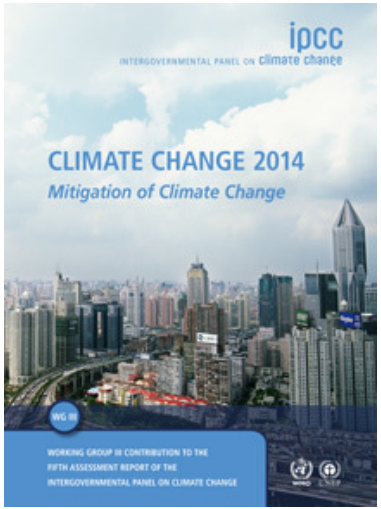
- **Internal variability:** The real world has natural swings and cycles (on top of trends).
- **Scientific uncertainty:** All of our models are imperfect (and we don't know which are best).
- **Societal uncertainty:** We can only guess what humans will do in the next decades.

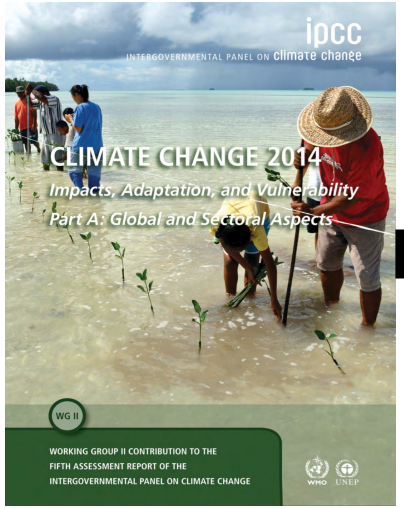


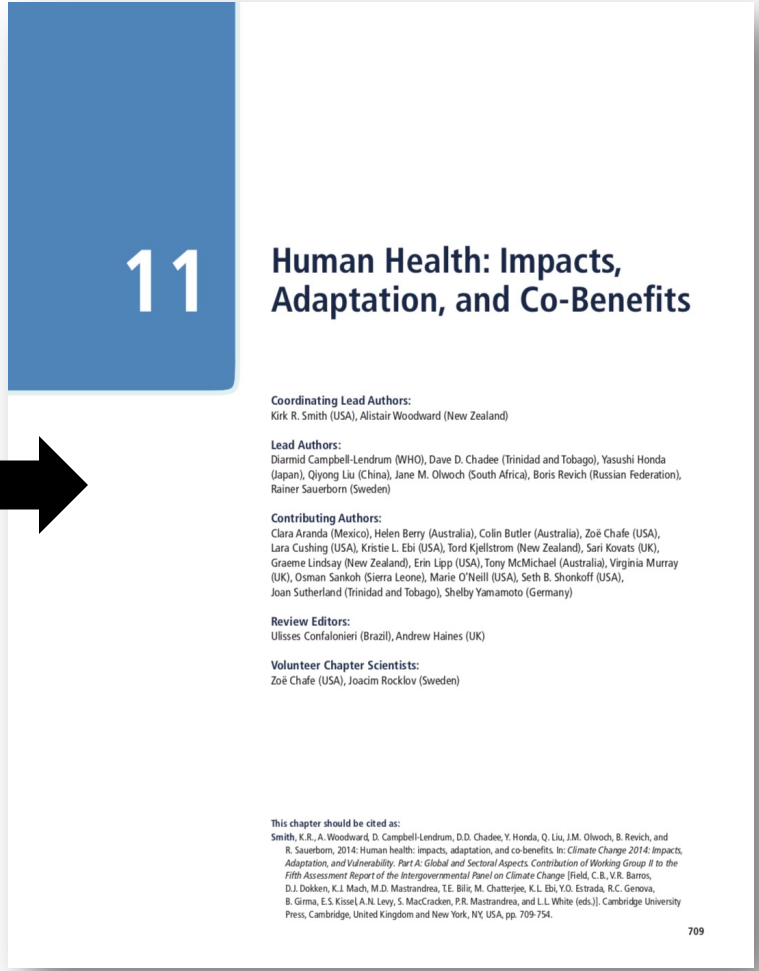


Source: IPCC AR5 WG1 SPM









11

Human Health: Impacts, Adaptation, and Co-Benefits

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Climate Change for the Health Professional
Learning Objectives

- Describe the difference between *weather* and *climate.*
- Distinguish between *natural climate variability* and *long-term climate change.*
- Explain the general mechanism of the *greenhouse effect.*
- Describe the measurement and evidence base of *climate drivers.*
- Explain the *societal dimensions of climate drivers.*
- Communicate the degree of *scientific consensus* on climate change and become familiar with the IPCC and other core resources.

References

Climate Modeling for Health Impacts (Chapter 13), in Global Climate Change and Human Health: From Science to Practice, Second Edition (Luber *et al.*, eds), John Wiley & Sons, ISBN 978-1-119-66795-7 (Paperback), 2021.

Climate Change and the Ocean (Chapter 9), in Physical Oceanography and Climate, First Edition, Cambridge University Press, ISBN 978-1-108-42386-1 (Hardback), ISBN 978-1-108-52959-4 (eBook), 2020.

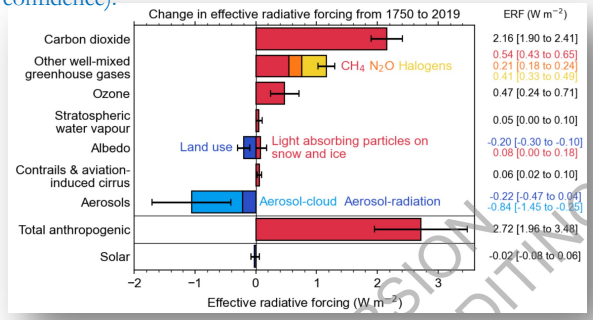
IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.

“Radiative forcing”

A *difference* between the incoming *solar* radiation and the outgoing *longwave* radiation.

Typically defined as a *change* in RF relative to preindustrial times *due to* a particular natural or anthropogenic factor.

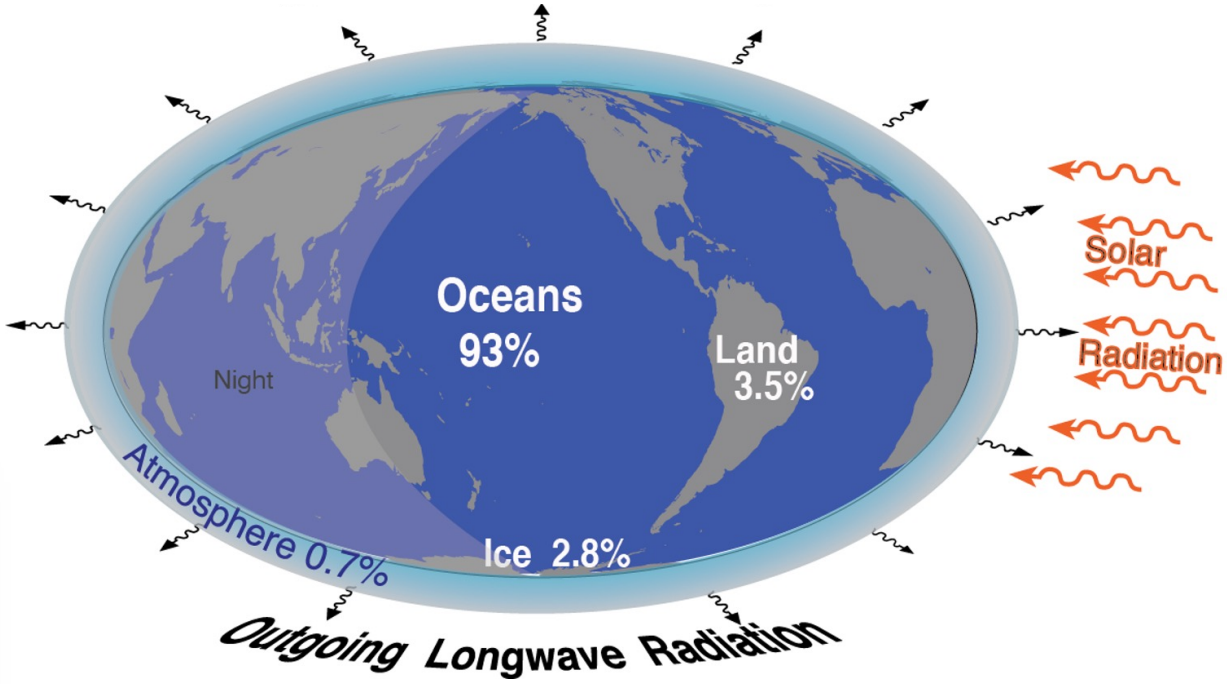
IPCC AR6 SPM: “A.4.1 Human-caused radiative forcing of **2.72 [1.96 to 3.48] W m^{-2} in 2019 relative to 1750** has warmed the climate system. This warming is mainly due to increased GHG concentrations, partly reduced by cooling due to increased aerosol concentrations. The radiative forcing has increased by 0.43 W m^{-2} (19%) relative to AR5, of which 0.34 W m^{-2} is due to the increase in GHG concentrations since 2011 […] (high confidence).”



Source: IPCC AR6 WG1 Ch7 (Fig. 7.6)

First Law of Thermodynamics $\Delta U = Q - W$

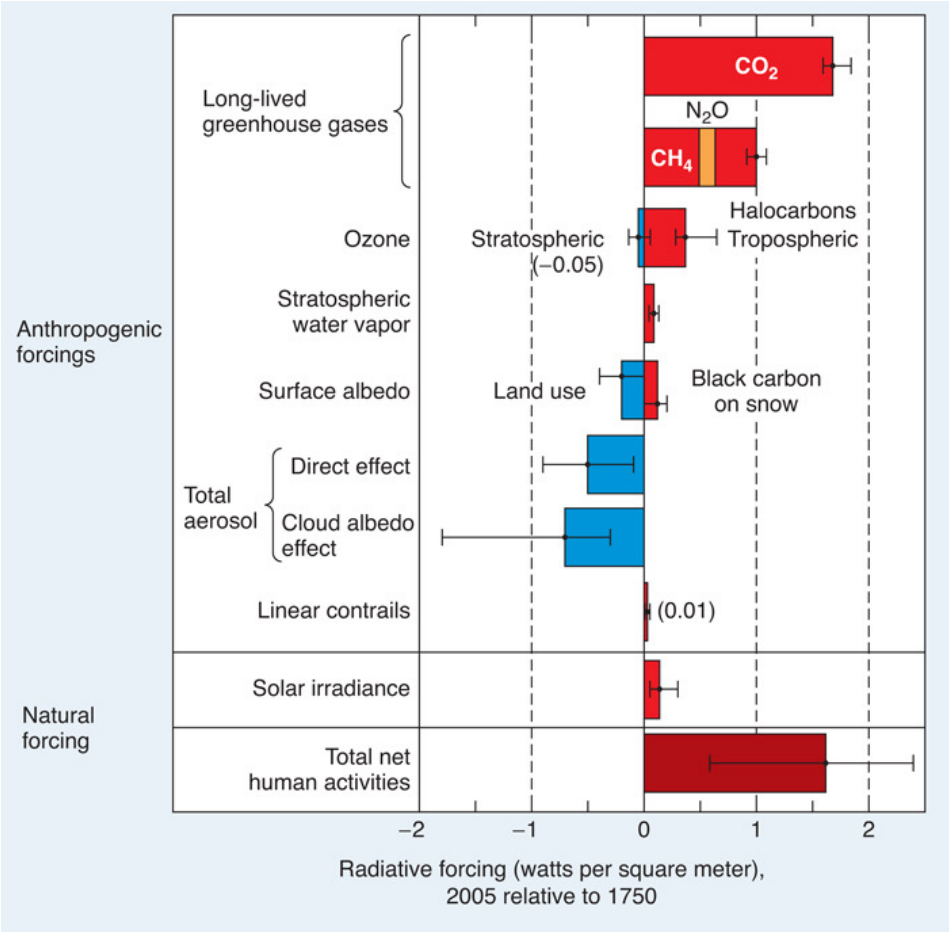
If you add energy Q to a system, its internal energy U must rise (assuming it can’t just put all of that energy Q into doing work W). Temperature is one measure of the internal energy of a system.



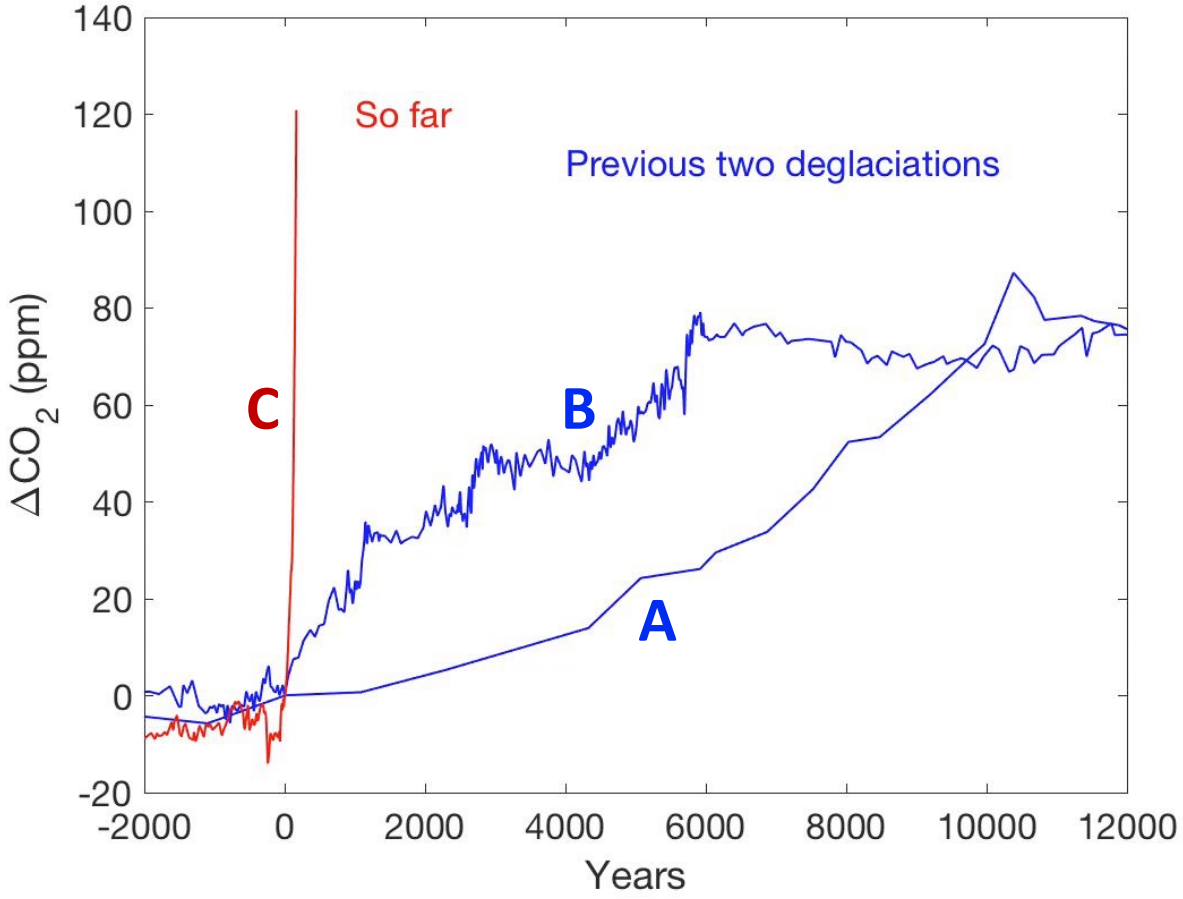
Outgoing radiation is decreasing, owing to increasing greenhouse gases in the atmosphere, and leading to Earth’s energy imbalance. The percentage going into each domain is indicated.

Source: Kevin Trenberth, CC BY-ND (https://theconversation.com/climate-change-is-relentless-seemingly-small-shifts-have-big-consequences-166139)

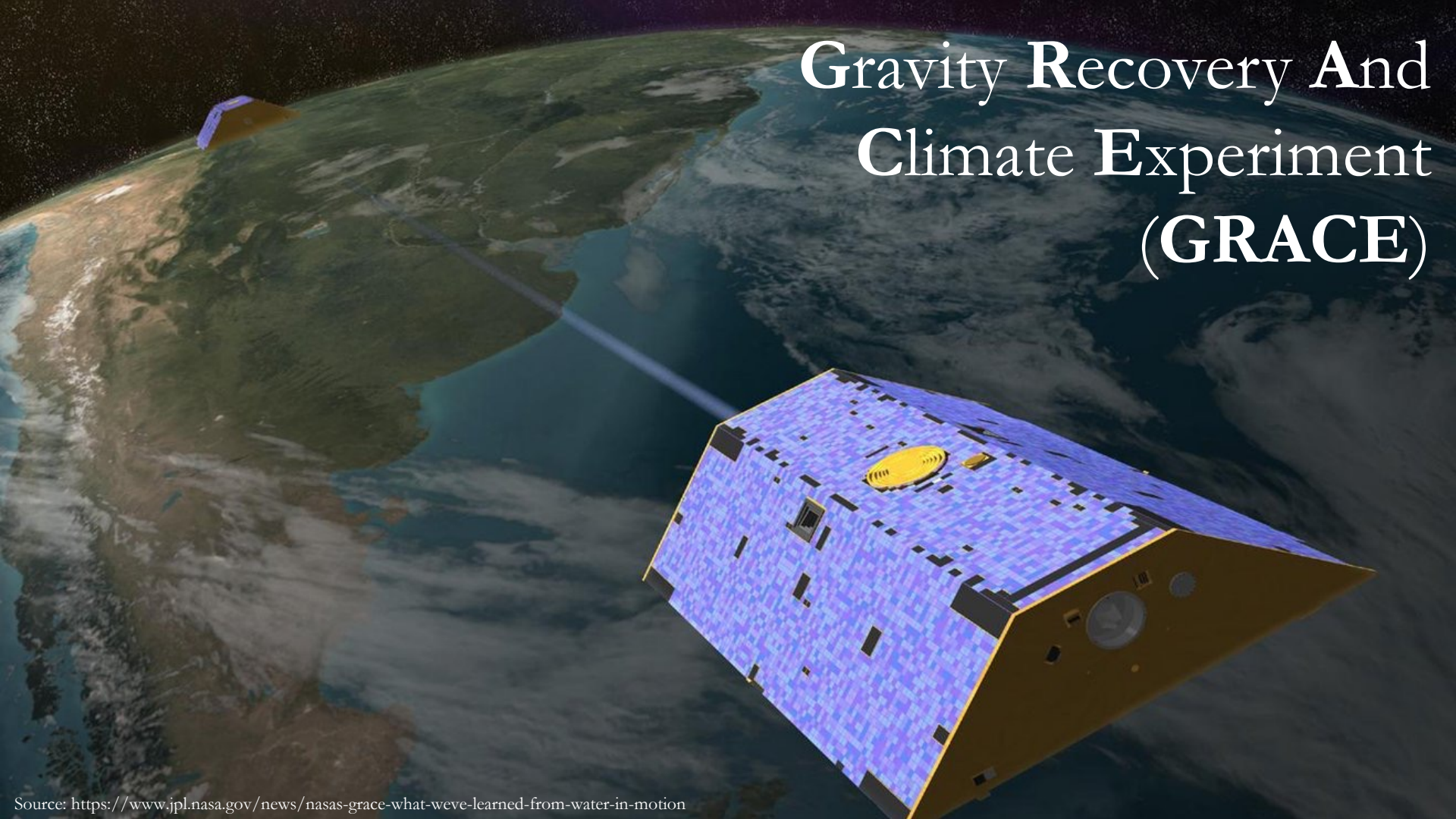
Figure 5.4. Changes in global mean radiative forcings, 1750-2005



E.A. Mathez, 2009, Climate Change: The Science of Global Warming and Our Energy Future, Columbia University Press. Source: Forster et al., 2007


140
120
100
80
60
40
20
0
-20
ΔCO_2 (ppm)
So far
Previous two deglaciations
C
B
A
-2000
0
2000
4000
6000
8000
10000
12000
Years

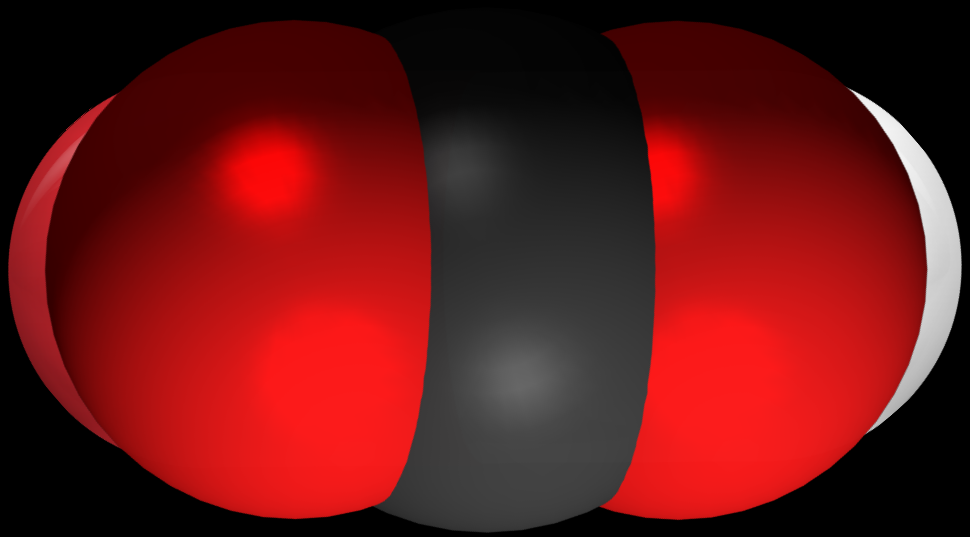
Gravity **R**ecovery **A**nd **C**limate **E**xperiment (**GRACE**)

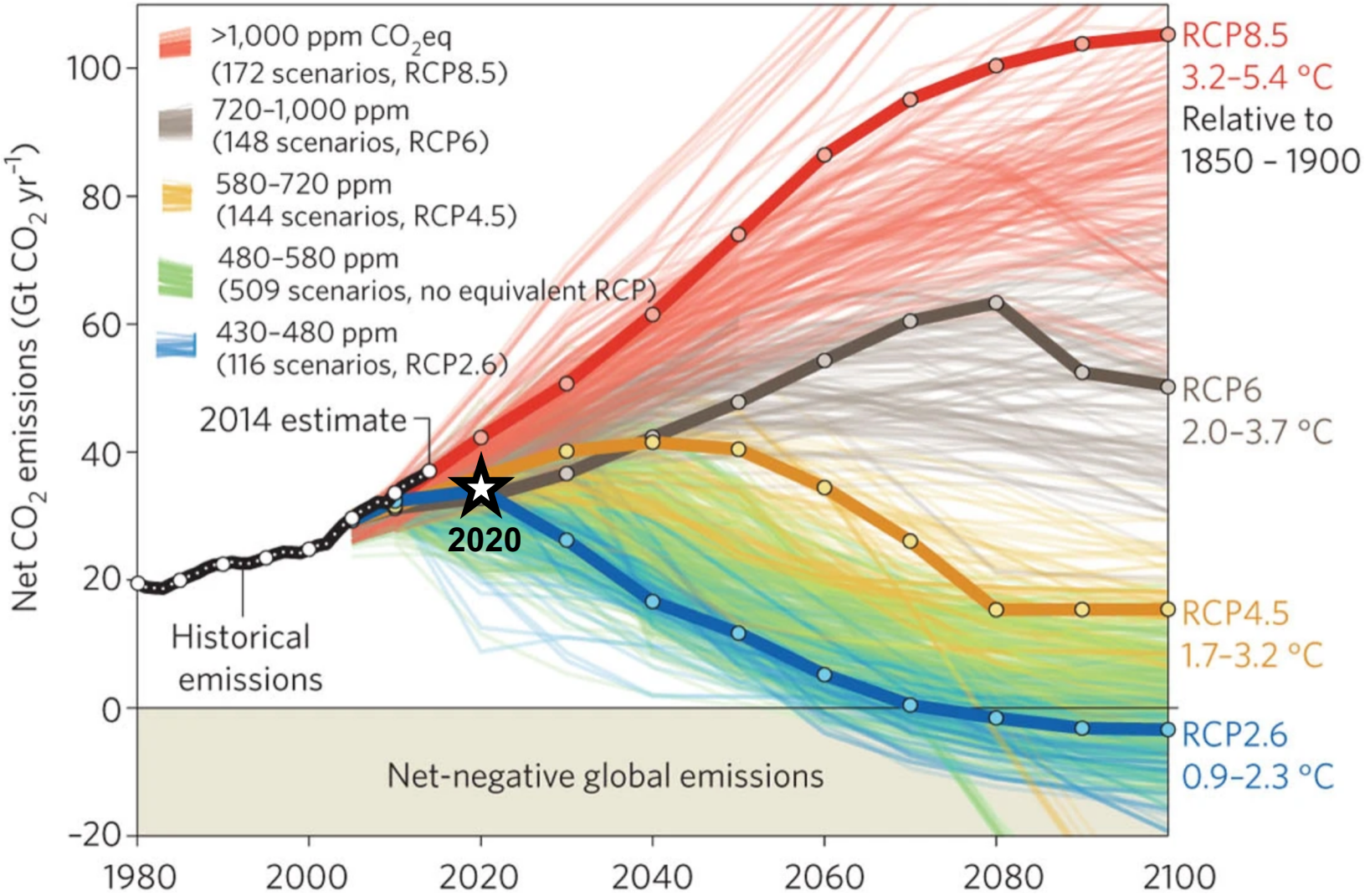


Source: https://www.jpl.nasa.gov/news/nasas-grace-what-weve-learned-from-water-in-motion

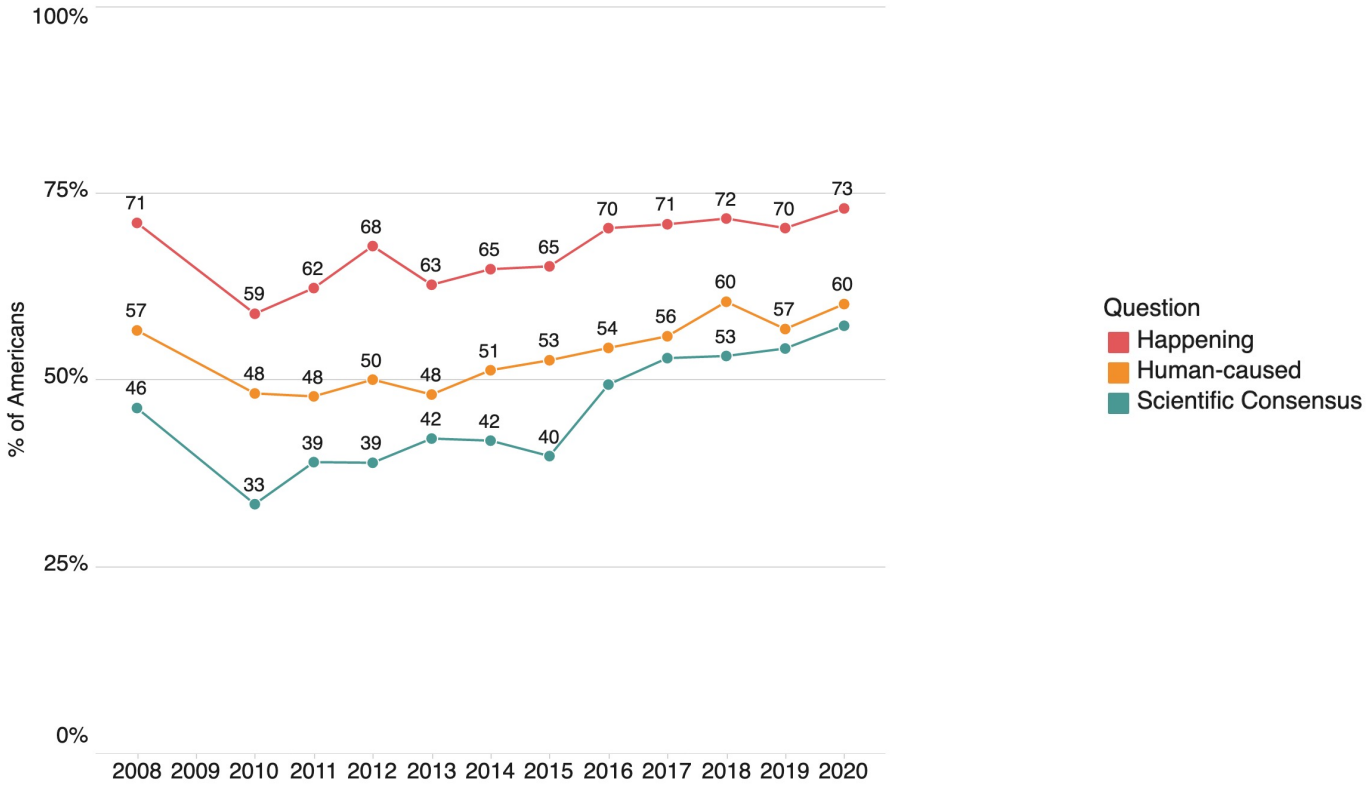
Is there a ~~cure~~?

prevention




>1,000 ppm CO_2eq
(172 scenarios, RCP8.5)
720–1,000 ppm
(148 scenarios, RCP6)
580–720 ppm
(144 scenarios, RCP4.5)
480–580 ppm
(509 scenarios, no equivalent RCP)
430–480 ppm
(116 scenarios, RCP2.6)
2014 estimate
2020
Historical emissions
Net-negative global emissions
Net CO_2 emissions (Gt CO_2 yr^{-1})
100
80
60
40
20
0
-20
1980
2000
2020
2040
2060
2080
2100
RCP8.5
3.2–5.4 °C
Relative to
1850 – 1900
RCP6
2.0–3.7 °C
RCP4.5
1.7–3.2 °C
RCP2.6
0.9–2.3 °C

Estimated % of adults who believe: …, 2020



YALE PROGRAM ON Climate Change Communication

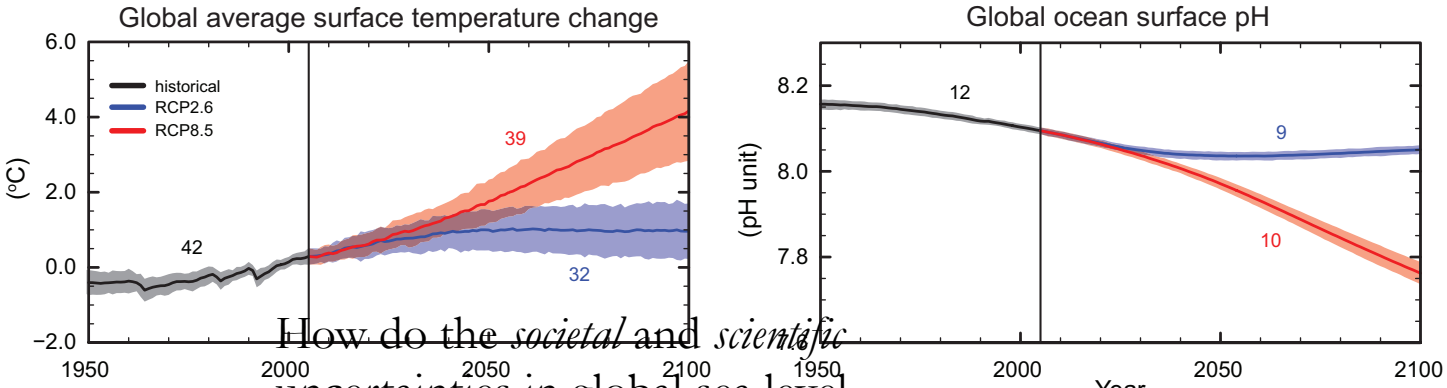
GEORGE MASON UNIVERSITY CENTER for CLIMATE CHANGE COMMUNICATION

Source: https://climatecommunication.yale.edu/visualizations-data/ycom-us/

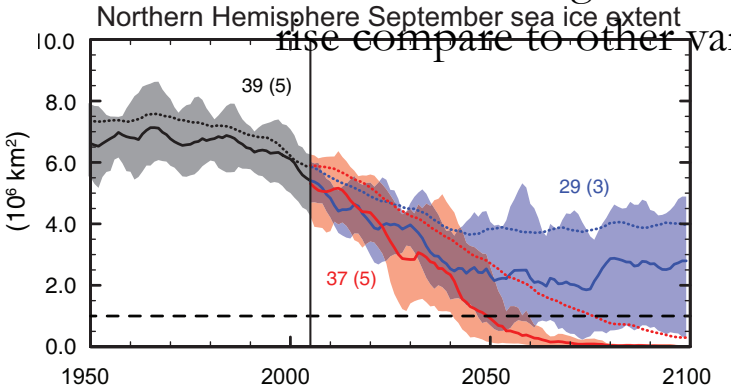
Intergovernmental Panel on Climate Change

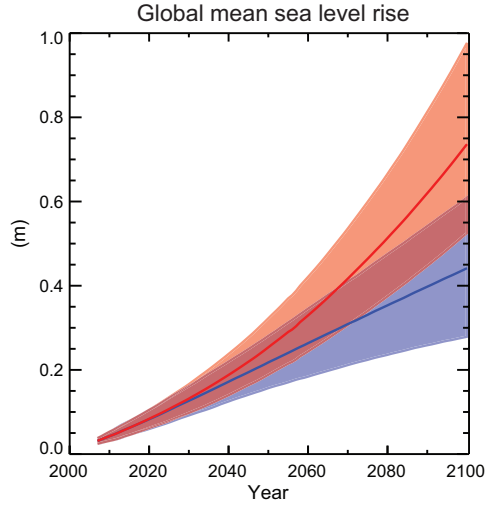
“Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen.”[13]

“Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems.”[14]



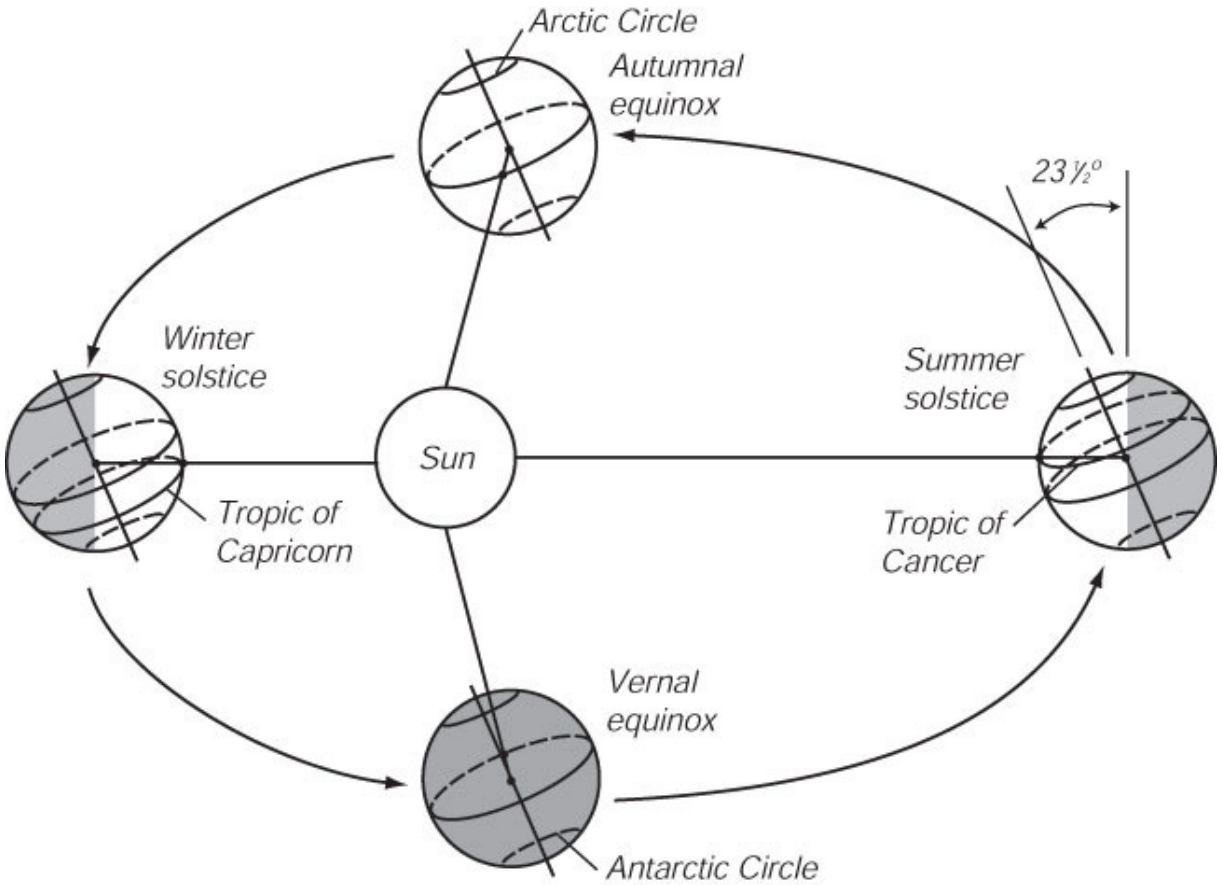
How do the *societal* and *scientific* uncertainties in global sea level rise compare to other variables?





Source: IPCC AR5 WG1 SPM

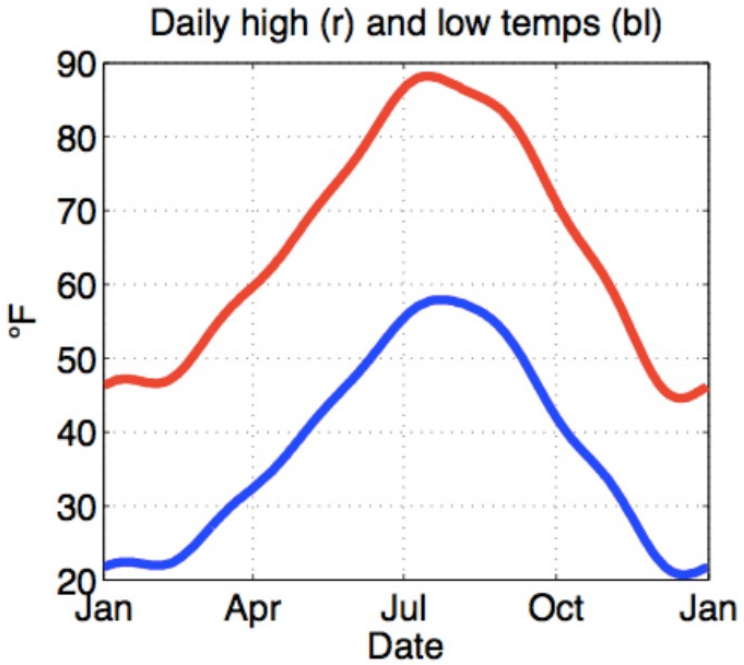
Example of "Natural climate variability that humans *might* recognize" (depending on latitude)

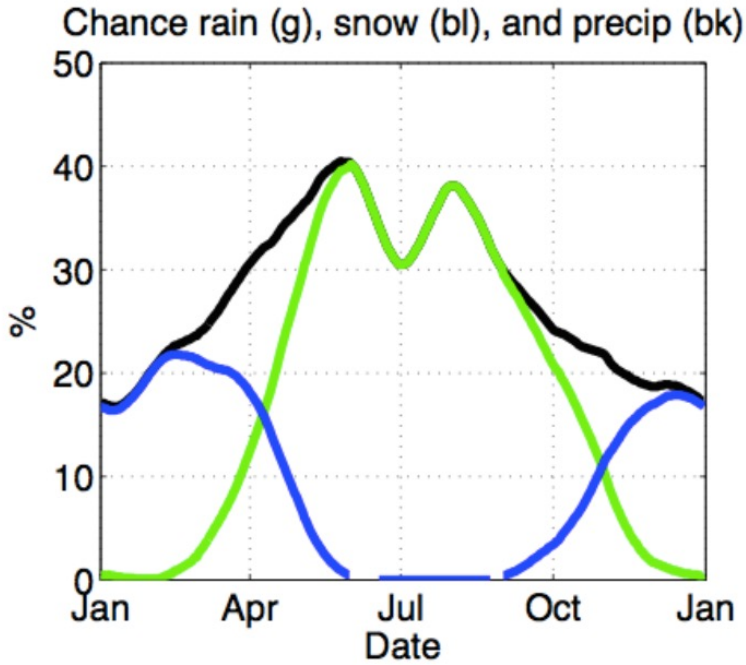


Example of "Natural climate variability that humans *might* recognize" (depending on latitude)

Average climate in Boulder, CO

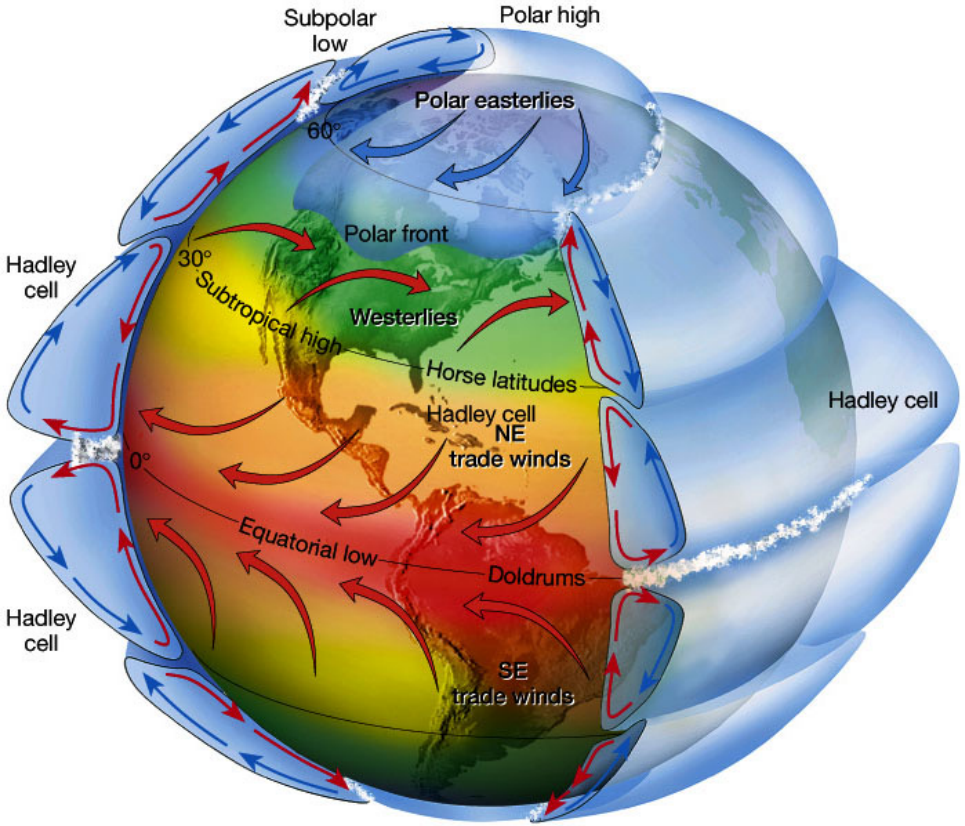
The following graphs describe the average year (representing 1981-2010) in Boulder, CO in terms of temperature and precipitation.



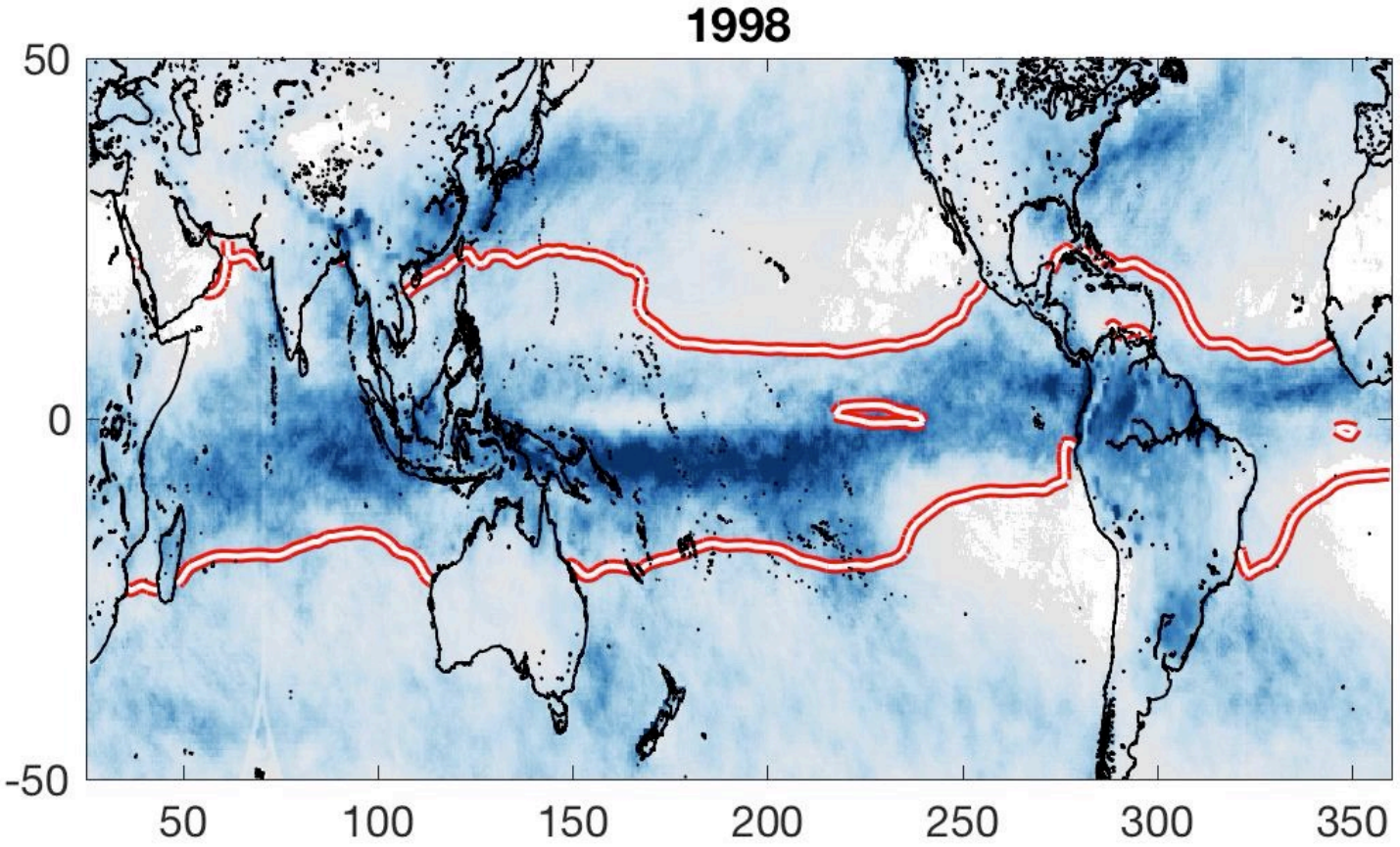


https://www.colorado.edu/oclab/more/boulder-climate

Example of "Natural climate variability that humans *might* recognize" (depending on latitude)



Example of "Natural climate variability that humans *might* recognize" (depending on latitude)



Example of "Natural climate variability that humans probably *don't* recognize"

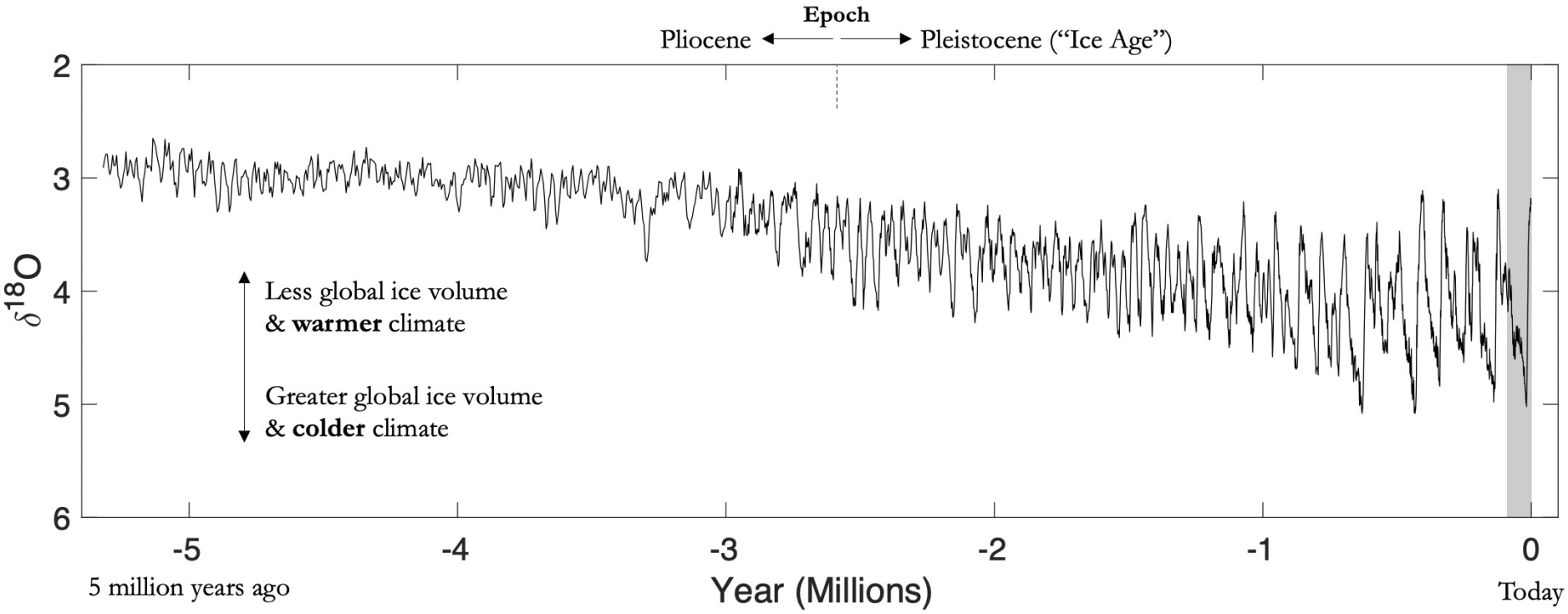


Figure 8.6. Record of oxygen isotope fraction ($\delta^{18}O$) from seafloor sediment cores, reflecting general variations in global climate including global ice volume over the past 5.3 million years. Note the reversed y–axis; lesser values of $\delta^{18}O$ (higher on the graph) represent warmer global climate and lesser ice volume, and greater values of ($\delta^{18}O$) (lower on the graph) represent colder global climate and greater ice volume. The record is a composite of 57 globally distributed records produced by Lisiecki and Raymo (2005). The inset zooms into the last 150 thousand years, revealing the most recent glacial cycle and the boundary between the Pleistocene and Holocene (present) epochs at ~ 11.7 thousand years ago.

Example of "Natural climate variability that humans probably *don't* recognize"

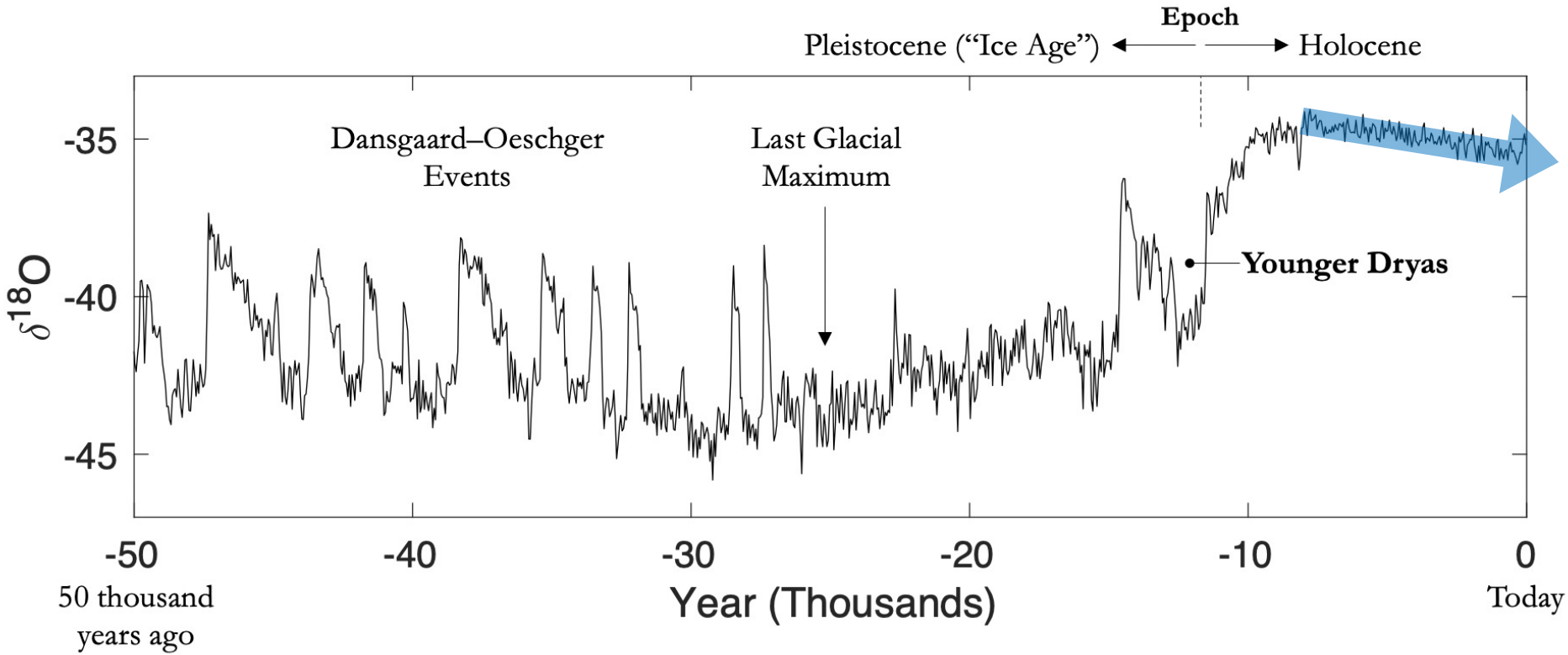
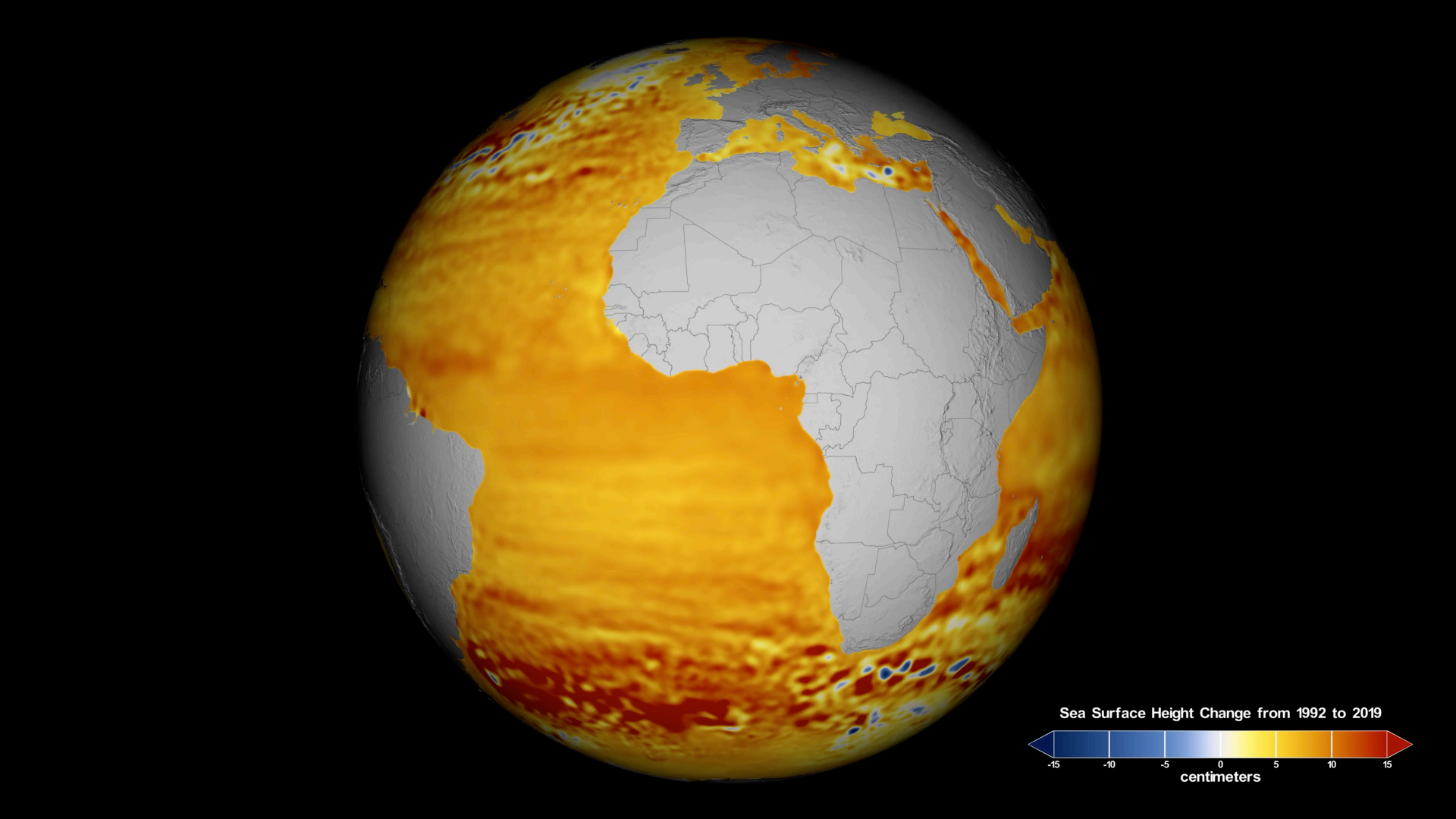


Figure 8.7. Record of oxygen isotope fraction ($\delta^{18}O$) from the North Greenland Ice Core Project (NGRIP), reflecting general variations in Northern Hemisphere climate including the response to global ice volume over the past 123,000 years (only the last 50,000 years are shown here). Greater values of $\delta^{18}O$ (higher on the graph) represent warmer Northern Hemisphere climate and lesser global ice volume, and lesser values of ($\delta^{18}O$) (lower on the graph) represent colder Northern Hemisphere climate and greater global ice volume. Note the greater detail in the ice core record than in the equivalent time period from the seafloor sediment cores (rightmost one–third of the inset of Figure 8.5). Dansgaard–Oeschger Events, the Last Glacial Maximum (~26.5 thousand years ago) and the Younger Dryas are labeled.


Sea Surface Height Change from 1992 to 2019
-15
-10
-5
0
5
10
15
centimeters

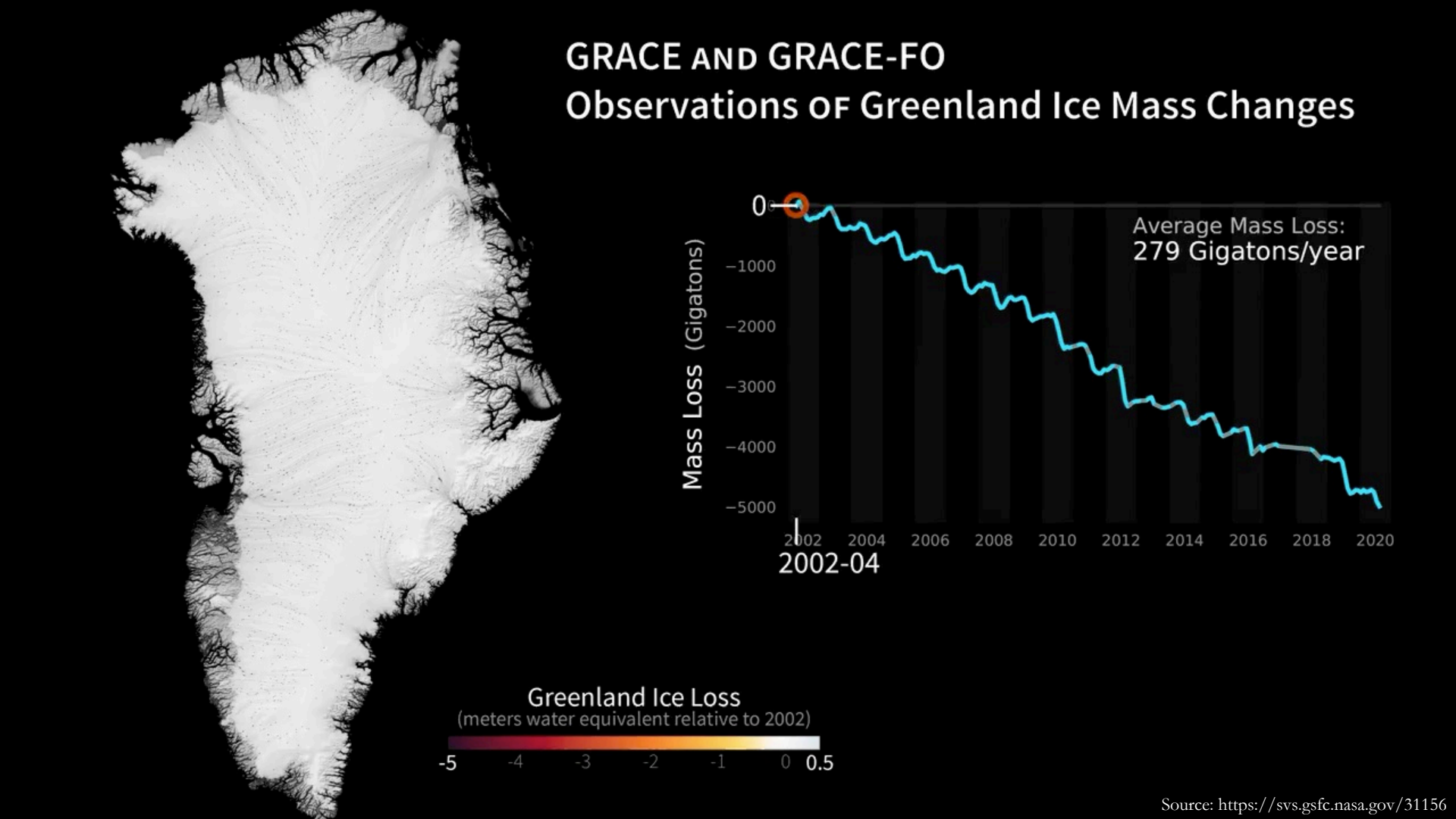
OUR OCEAN ABSORBS MORE THAN 90% OF THE HEAT TRAPPED BY HUMAN-PRODUCED GREENHOUSE GASES

This extra heat causes the sea level to rise.

As water warms, its molecules move and interact more, causing the water to take up more space. If you've used a mercury thermometer, you've seen the same effect, **thermal expansion**, in action.

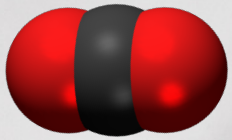
+

The extra heat causes the **melting of ice sheets and glaciers** on land. Greenland, in the Arctic, is warming about two times faster than the rest of the planet.



Source: https://svs.gsfc.nasa.gov/31156

Emissions



Concentration

- How much CO_2 is *added to* the atmosphere in a given year
- **34 Gt** (gigatons) of CO_2 in 2020
- Increasing by a few % each year *

  * Except for ~7% reduction in 2020 due to COVID
- This is what *humans control* (via fossil fuel combustion).

- How much CO_2 is *present in* the atmosphere in a given year
- **414 ppm** (parts per million) in 2020
- Increasing by 2–3 ppm each year
- This is what the *climate responds to* (via the greenhouse effect).

Note that even if—or when—emissions level off or start to decline soon, concentration will continue to rise…