

**Some thoughts about  
Global Warming and  
Global Climate Change  
(Part 2)**

**James Flaten**

**NASA's MN Space Grant Consortium**

**U of MN – Twin Cities**

# Some take-aways

- Climate always changes, but usually does so “slowly”
- On-going climate change is happening much faster than “nature” can explain (but we know why)
- Climate change can lead to “mass extinctions” of entire species (and other things, including cultures)
- People are paying attention and starting to try to correct/limit the damage we are responsible for
- Human effort is currently falling far short of what is needed to stop, much less reverse, climate change

# More take-aways

- By the end of this century large swaths of the earth will be uninhabitable (by today's standards) due to
  - (a) overheating, lack of water, fires (in some areas)
  - (b) sea level rise, flooding (in other areas)
- The problem doesn't go away by the year 2100 – that is just the year beyond which most models don't go
- Despite people's best efforts, dramatic (negative) social and economic changes are probably unavoidable
- The Earth will survive; people will too (probably)

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EXHIBITION — APR 5, 2019-JAN 10, 2020

# KLIMALAB

An Exhibition about the  
Climate, Nature and People.



Photo: Øystein Thorvaldsen

[www.nobelpeacecenter.org/en/](http://www.nobelpeacecenter.org/en/)



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## 7 OF THE BEST TED TALKS ABOUT CLIMATE CHANGE

These are definitely “ideas worth spreading.”

<https://www.climaterealityproject.org/blog/7-best-ted-talks-about-climate-change>

AN INCONVENIENT SEQUEL

# TRUTH TO POWER

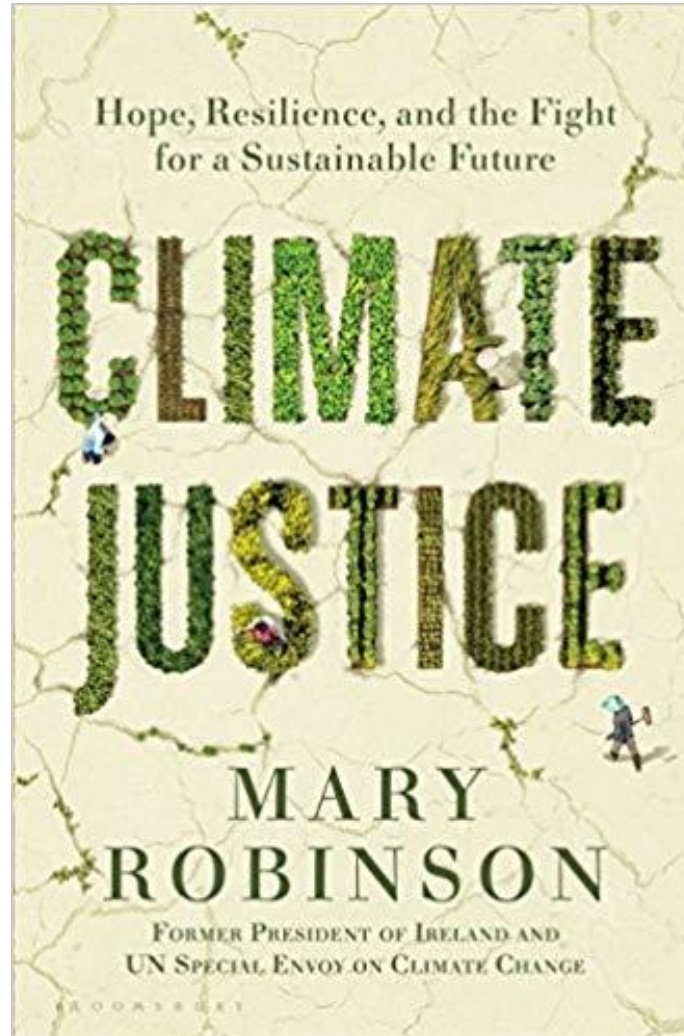
Your action handbook to learn the science, find your voice, and help solve the climate crisis



**AL GORE**

AUTHOR OF THE #1 NEW YORK TIMES BESTSELLER AN INCONVENIENT TRUTH

NEW YORK TIMES  
BESTSELLER



The  
Uninhabitable  
Earth

*Life After Warming*

David  
Wallace-Wells

# Why TIME Devoted an Entire Issue to Climate Change



Some article titles:

- 2050: How Earth Survived
- Why I Have Hope for the Climate-Change Battles to Come (by Al Gore)
- The Hottest City on Earth
- The Tipping Point: Amazon on the Brink
- The Great Green Wall (Project) of Africa
- Take a Walk on the Rewilding Side
- The Climate Caucuses
- No Person is an Island
- Can We Innovate Our Way Out Of This Mess?

BY **EDWARD FELSENTHAL** SEPTEMBER 12, 2019

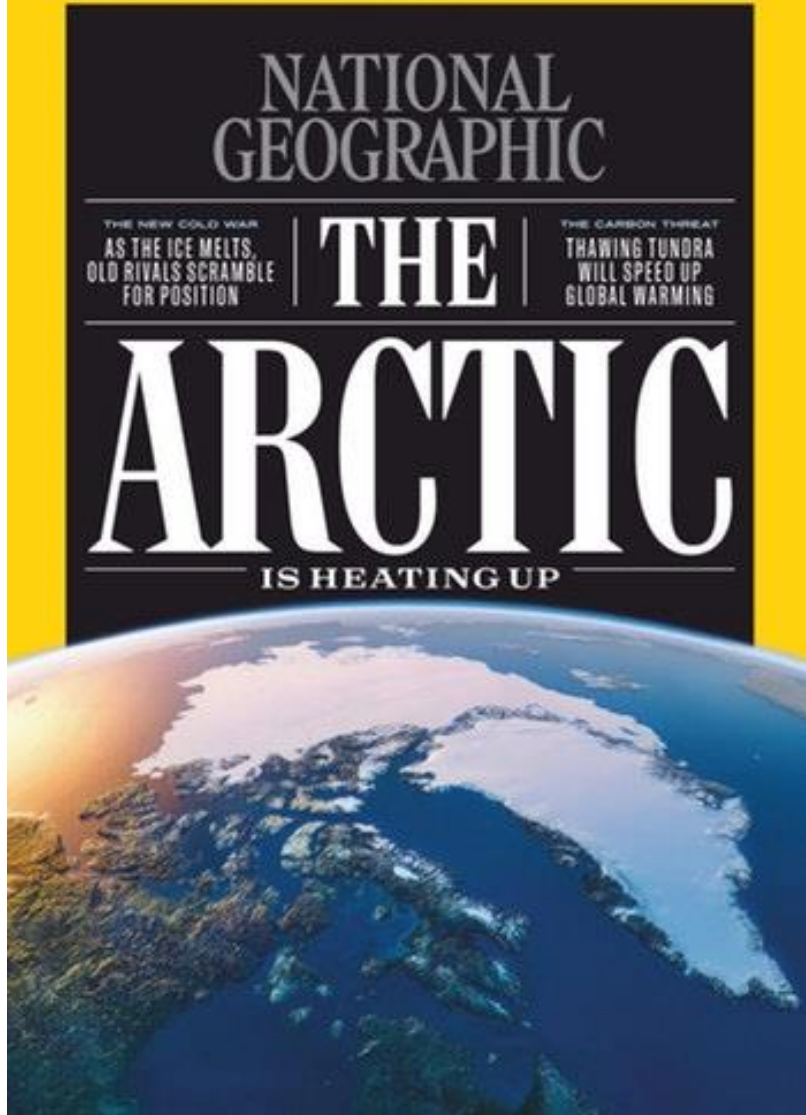
<https://time.com/5669069/time-climate-change-issue/>



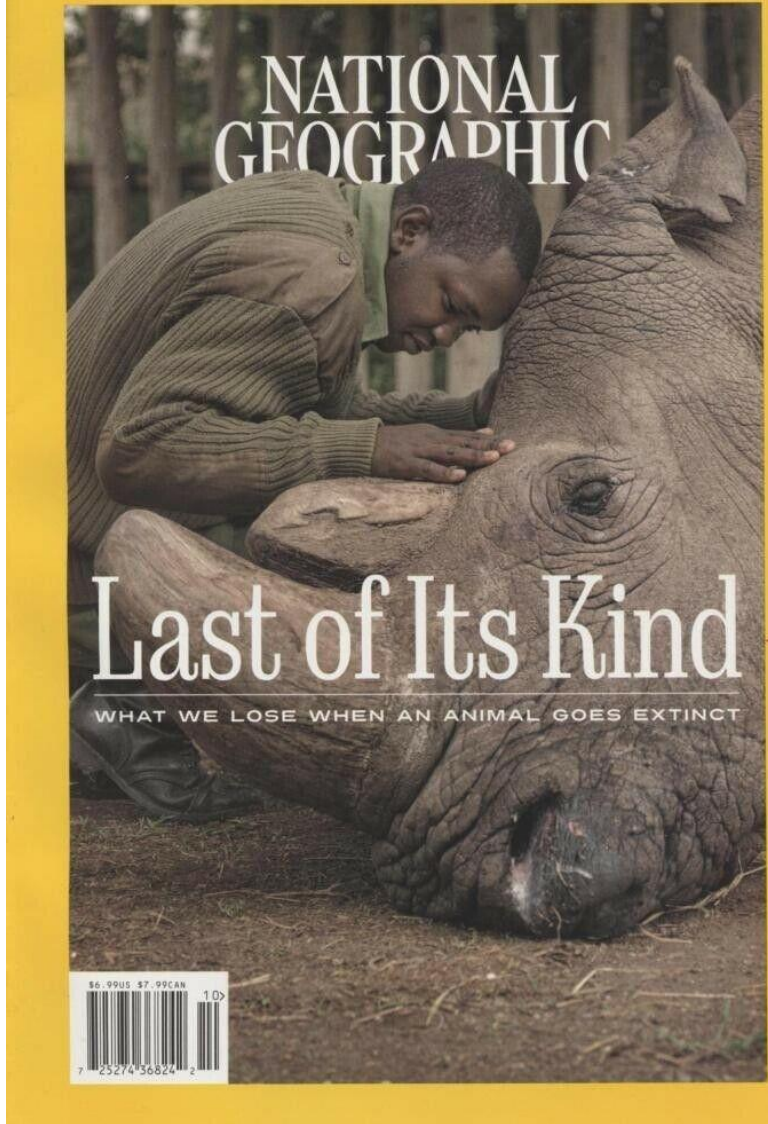
08.2019



09.2019



10.2019



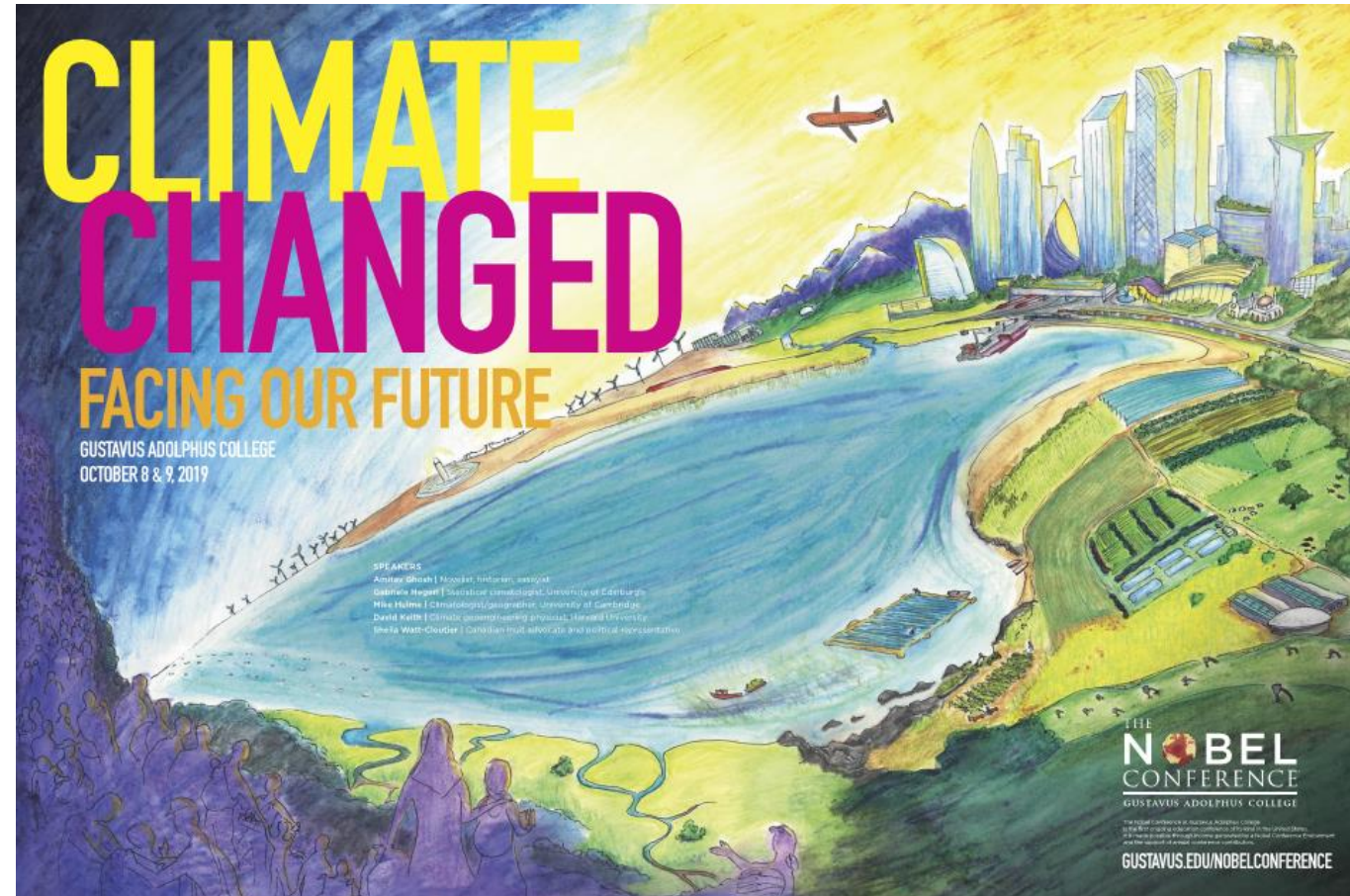
<https://www.nationalgeographic.com/magazine/>

# Gustavus Adolphus College Nobel Conference 55 (2019): *Climate Changed: Facing Our Future*

September 24 - 25, 2019

## Speakers

- Amitav Ghosh, novelist, historian, essayist
- Richard Alley, glaciologist, Penn State University
- Diana Liverman, geographer, University of Arizona
- Sheila Watt-Cloutier, Canadian Inuit advocate and political representative
- Gabriele Hegerl, statistical climatologist, University of Edinburgh
- Mike Hulme, climatologist/geographer, University of Cambridge
- David Keith, climate geoengineering physicist, Harvard University



<https://gustavus.edu/events/nobelconference/2019>

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# Nobel Conference 55: Climate Changed


10 videos • 2,006 views • Last updated on Sep 25, 2019





Gustavus Adolphus College


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**Dr. Richard Alley Presenting at Nobel Conference 55**  
Gustavus Adolphus College  
37:44
- 

**Dr. Diana Liverman Presenting at Nobel Conference 55**  
Gustavus Adolphus College  
43:21
- 

**Panel Discussion and Audience Q&A #2**  
Gustavus Adolphus College  
42:17
- 

**Sheila Watt-Cloutier Presenting at Nobel Conference 55**  
Gustavus Adolphus College  
38:44

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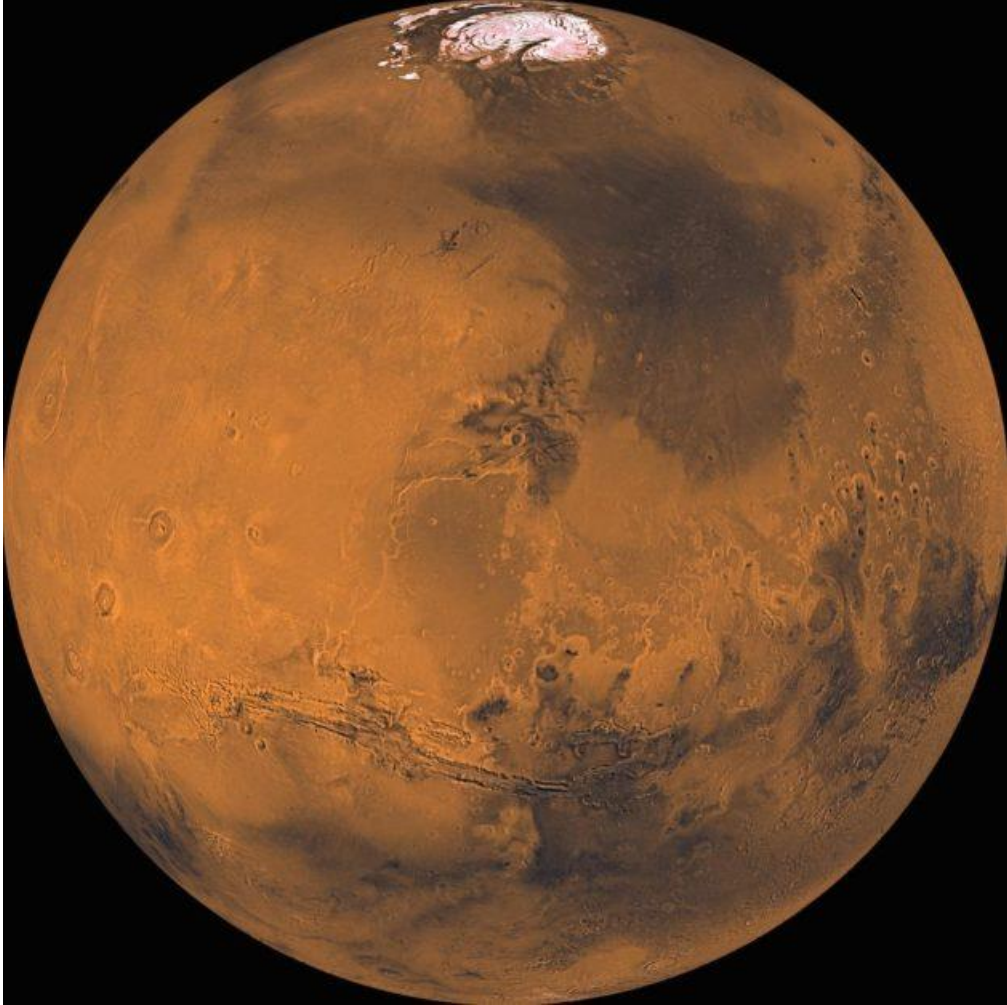


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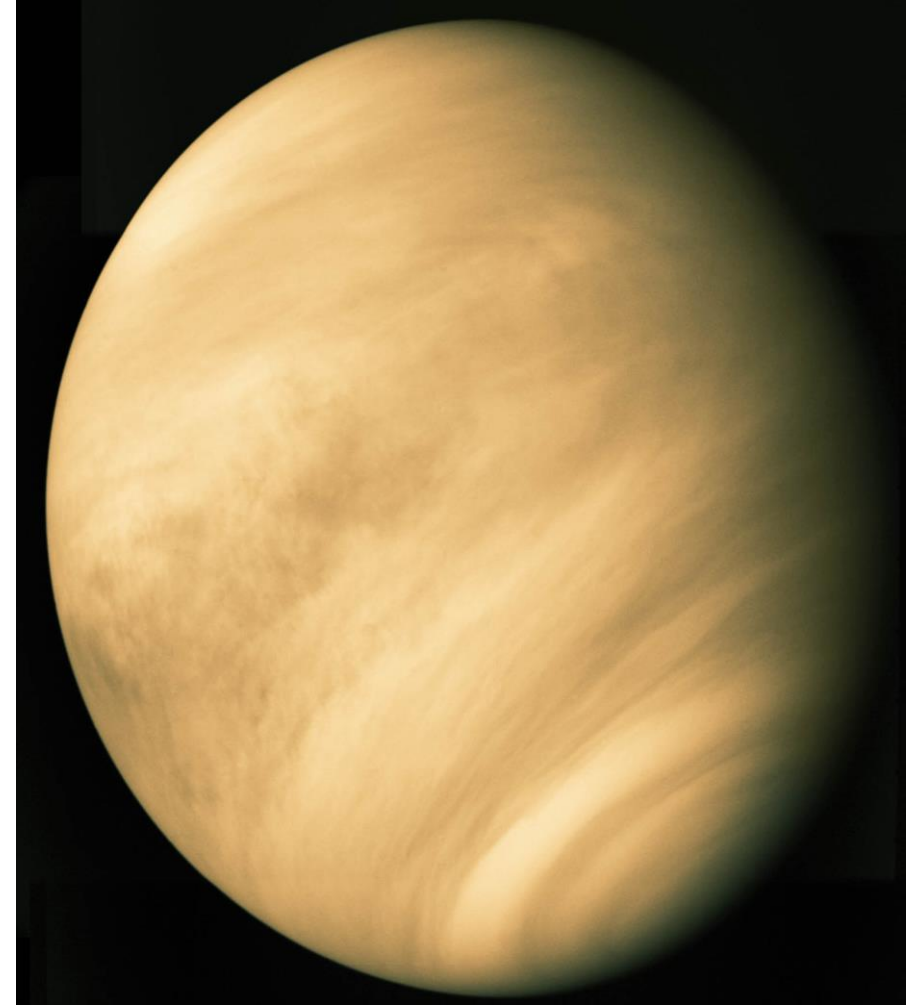
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Gustavus Adolphus College  
41:12
- 7 **Panel Discussion and Audience Q&A #3**  
Gustavus Adolphus College  
48:05
- 8 **Dr. David Keith Presenting at Nobel Conference 55**  
Gustavus Adolphus College  
43:11
- 9 **Dr. Mike Hulme Presenting at Nobel Conference 55**  
Gustavus Adolphus College  
36:19
- 10 **Panel Discussion and Audience Q&A #4**  
Gustavus Adolphus College  
58:34

# Cautionary Tales



Mars



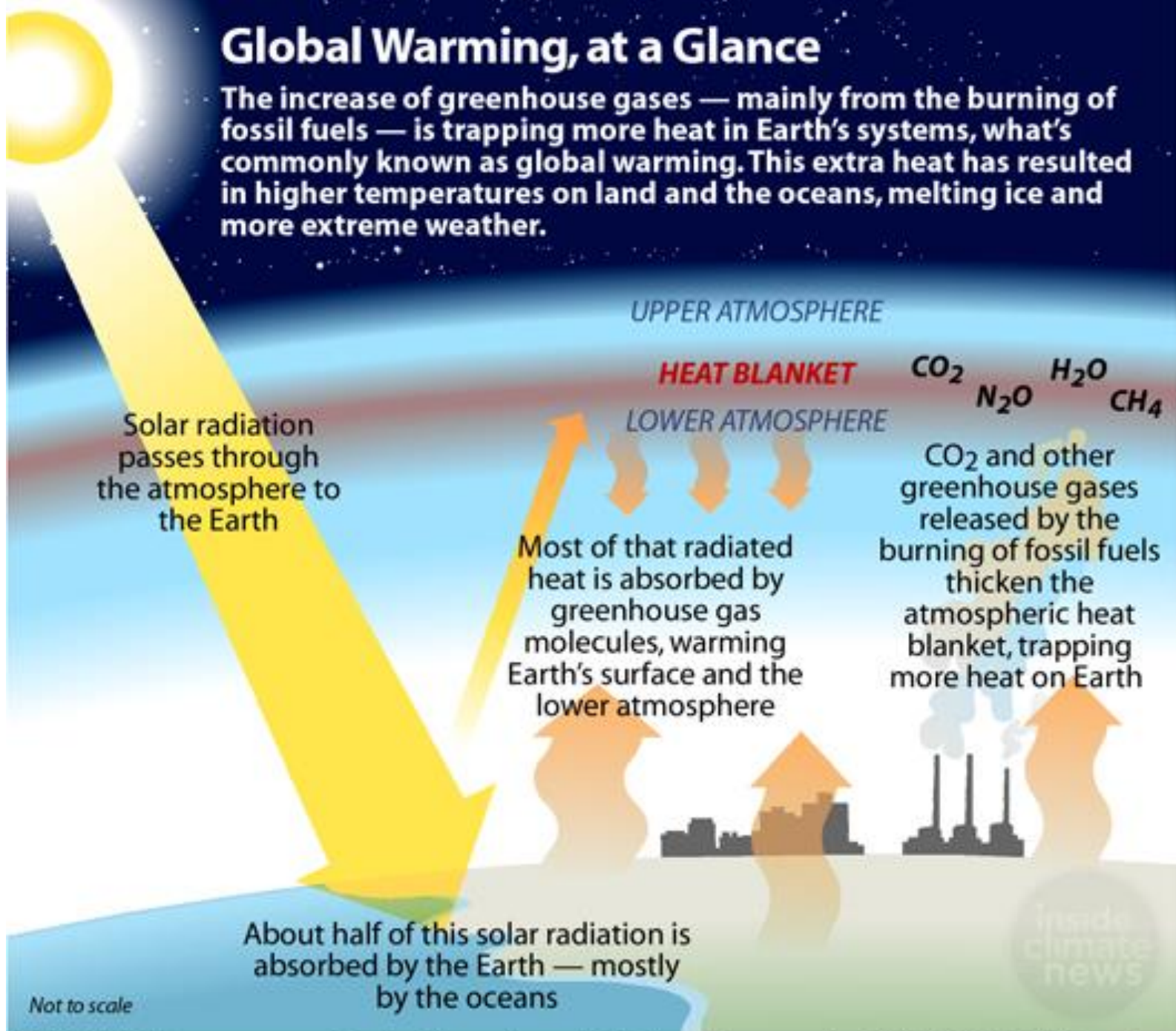
Venus

# What about the Earth?



# Global Warming, at a Glance

The increase of greenhouse gases — mainly from the burning of fossil fuels — is trapping more heat in Earth's systems, what's commonly known as global warming. This extra heat has resulted in higher temperatures on land and the oceans, melting ice and more extreme weather.



Not to scale

inside climate news

# The Biggest Sources of Greenhouse Gases

THAWING PERMAFROST

AIR TRANSPORT

OIL PRODUCTION

COAL MINING

COAL PLANTS

INDUSTRIAL PROCESSES

CROP BURNING

FOREST BURNING

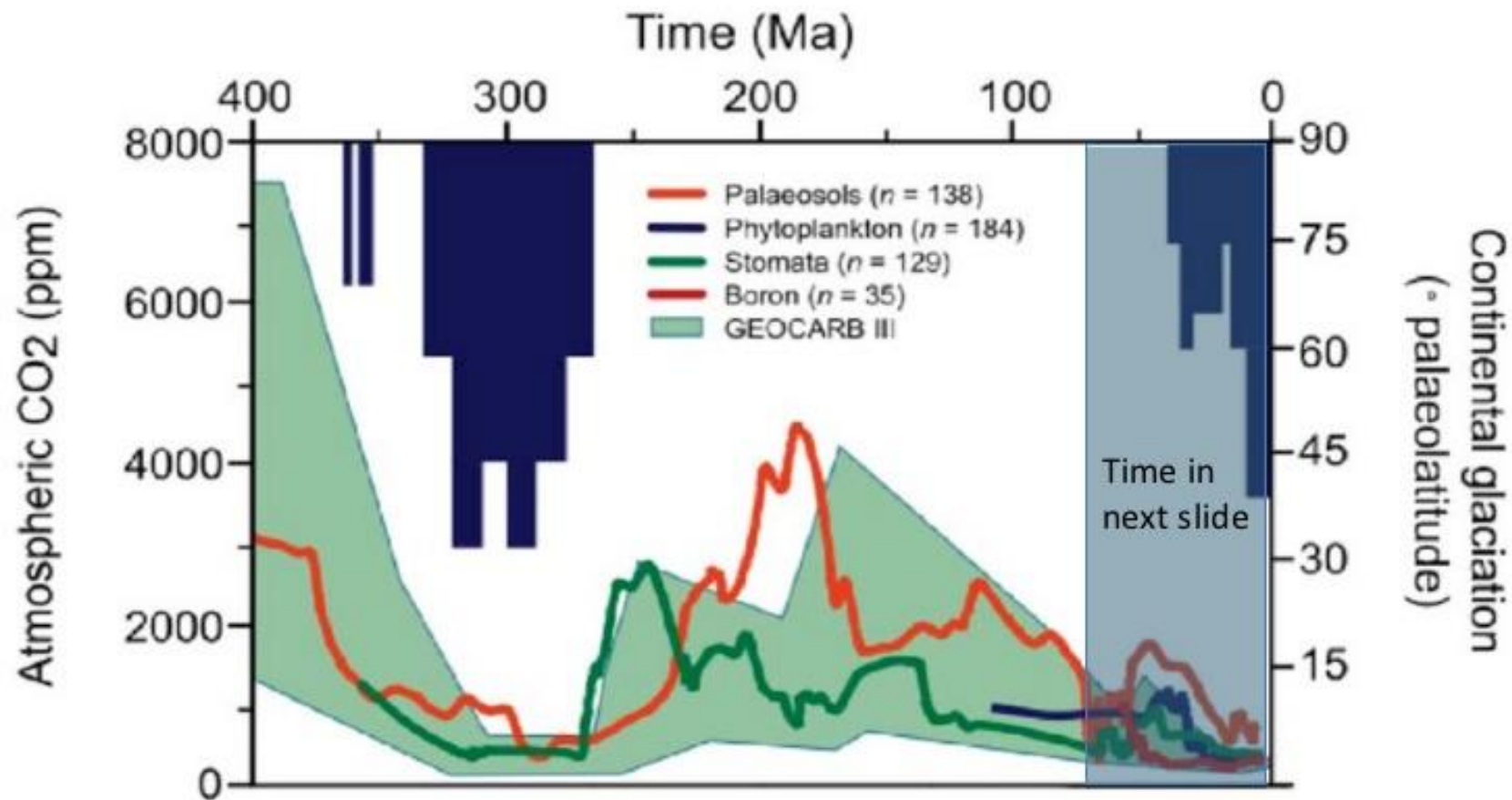
FERTILIZATION

LAND TRANSPORTATION

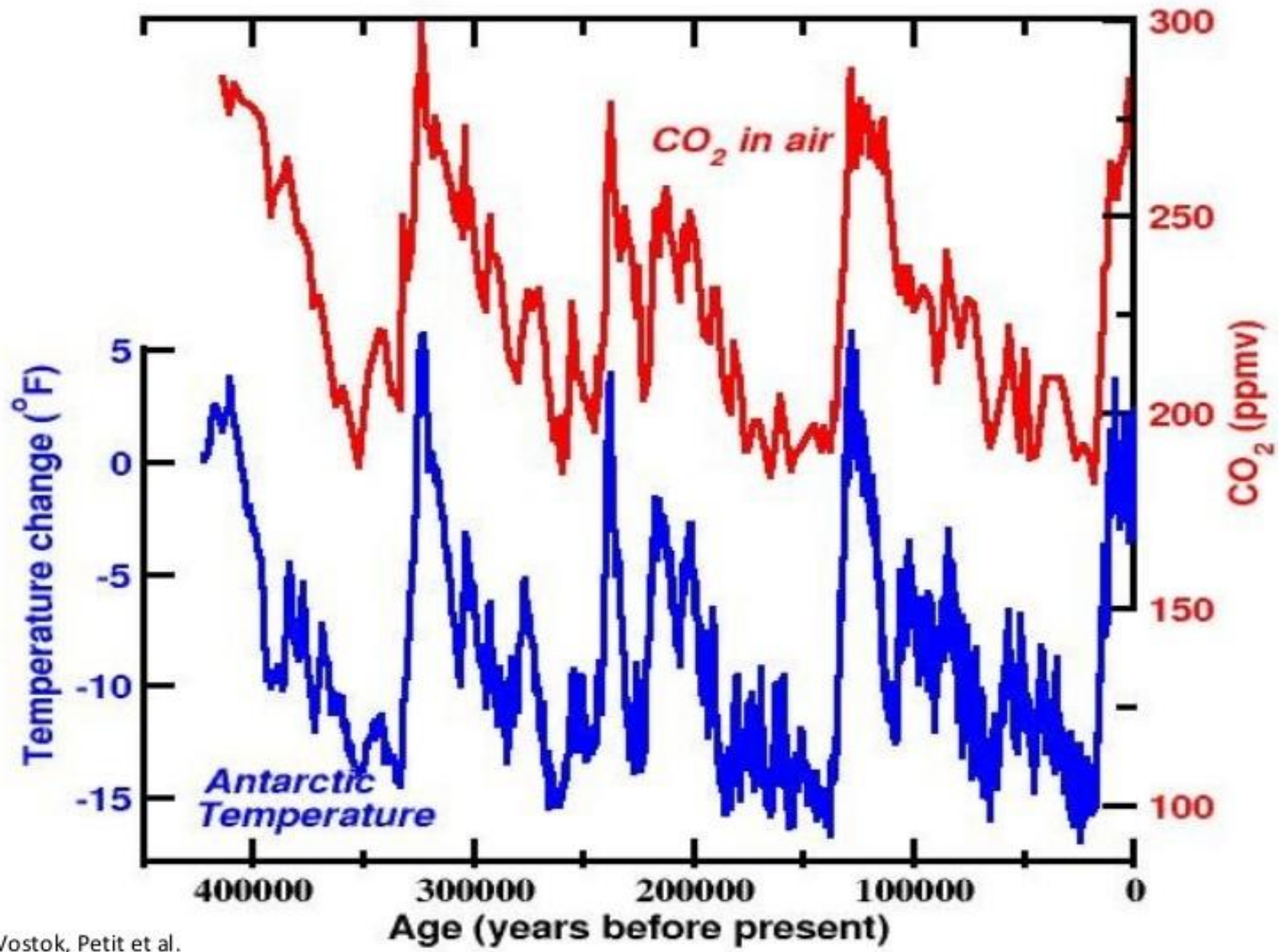
INDUSTRIAL AGRICULTURE

LANDFILLS





**Figure 4.24 Atmospheric CO<sub>2</sub> and continental glaciation 400 Ma to present.** Vertical blue bars, timing and palaeolatitudinal extent of ice sheets (after Crowley, 1998). Plotted CO<sub>2</sub> records represent five-point running averages from each of four major proxies (see Royer, 2006 for details of compilation). Also plotted are the plausible ranges of CO<sub>2</sub> derived from the geochemical carbon cycle model GEOCARB III (Berner and Kothavala, 2001). All data adjusted to the Gradstein et al. (2004) time scale. Continental ice sheets grow extensively when CO<sub>2</sub> is low. (after Jansen, 2007, that report's Figure 6.1)



Vostok, Petit et al.

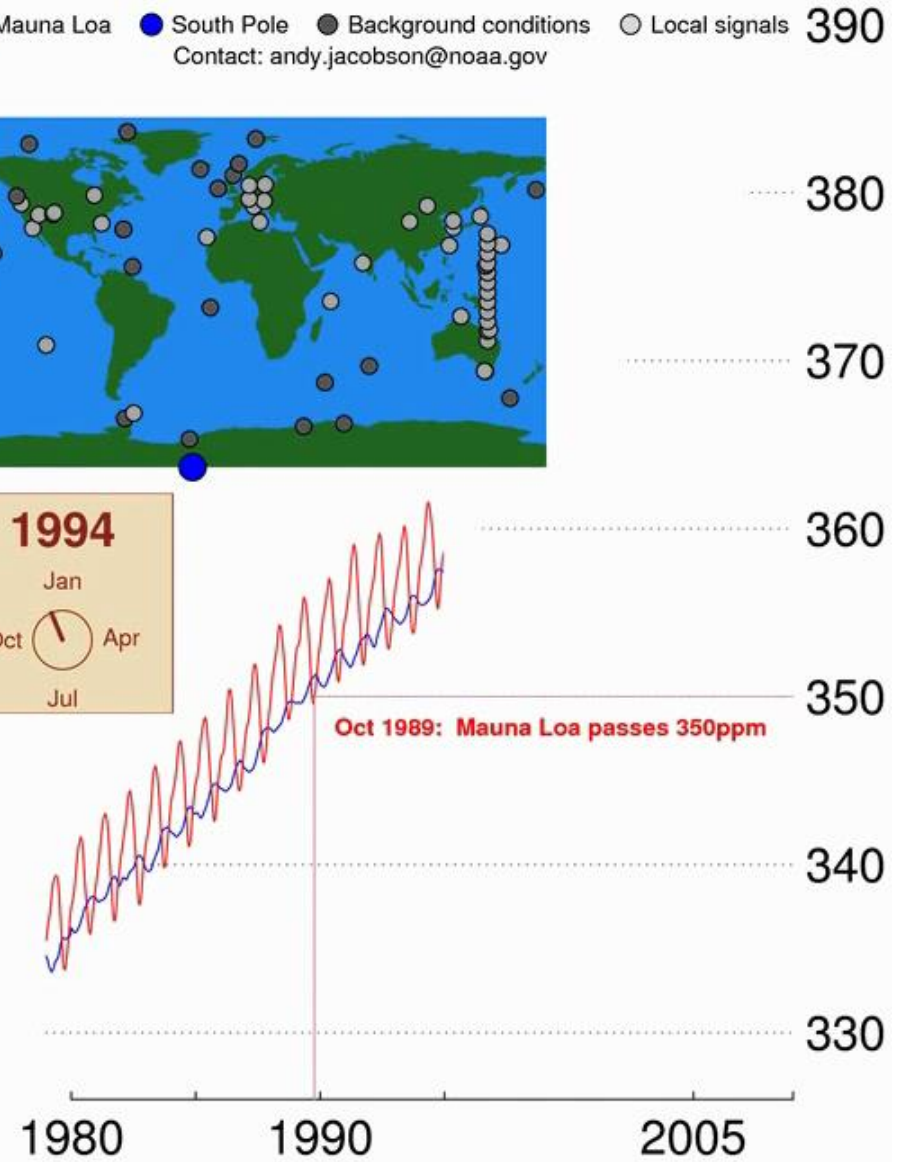
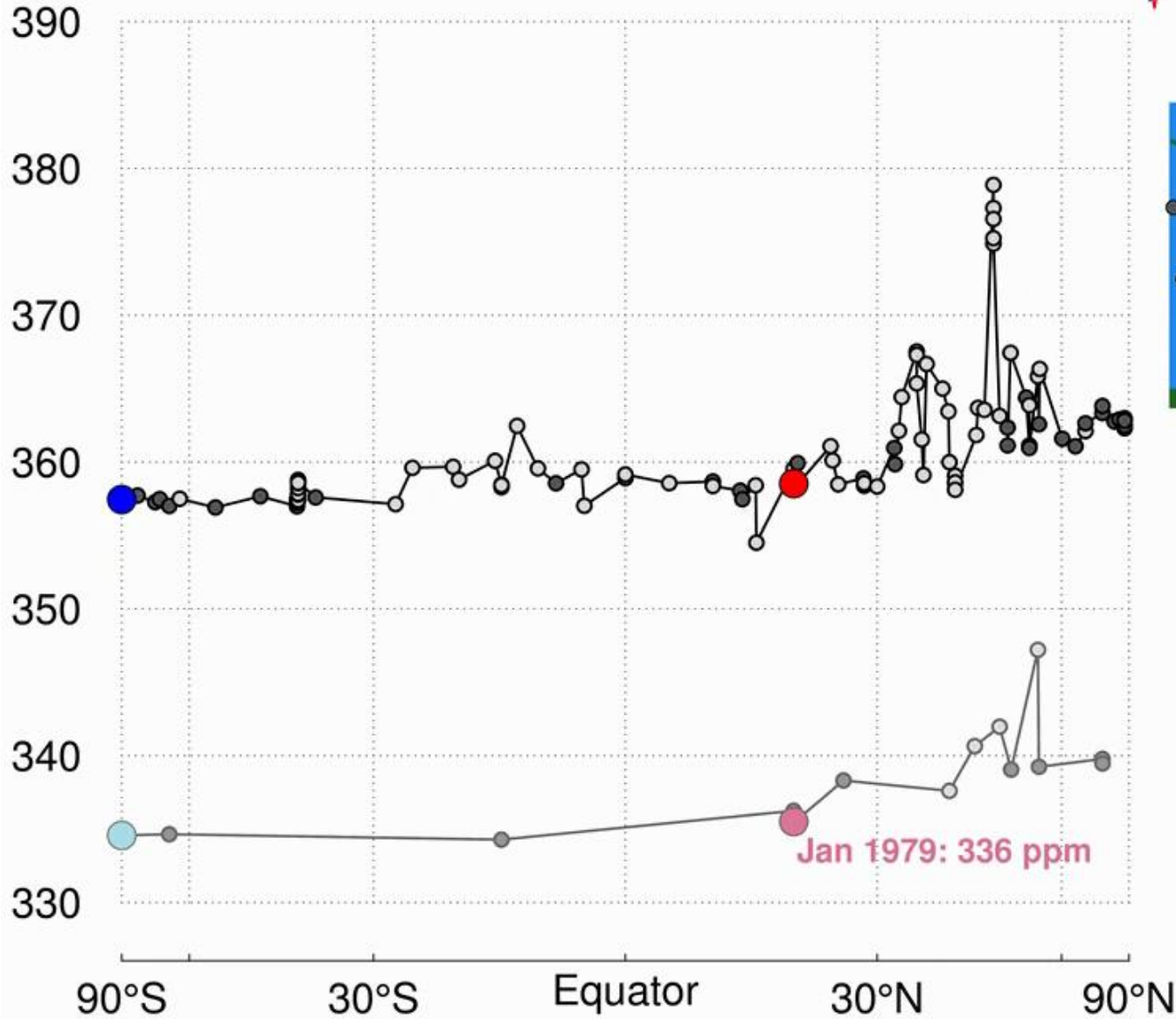
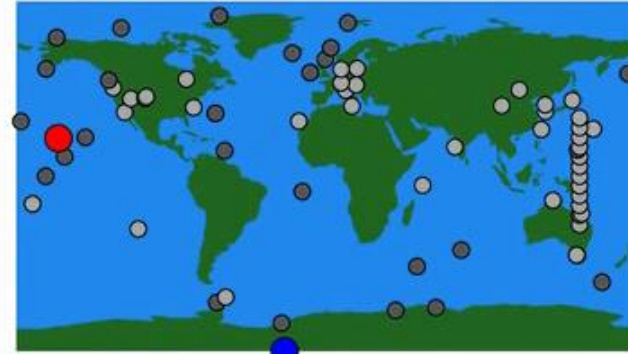
Prof. Richard B. Alley, Penn State

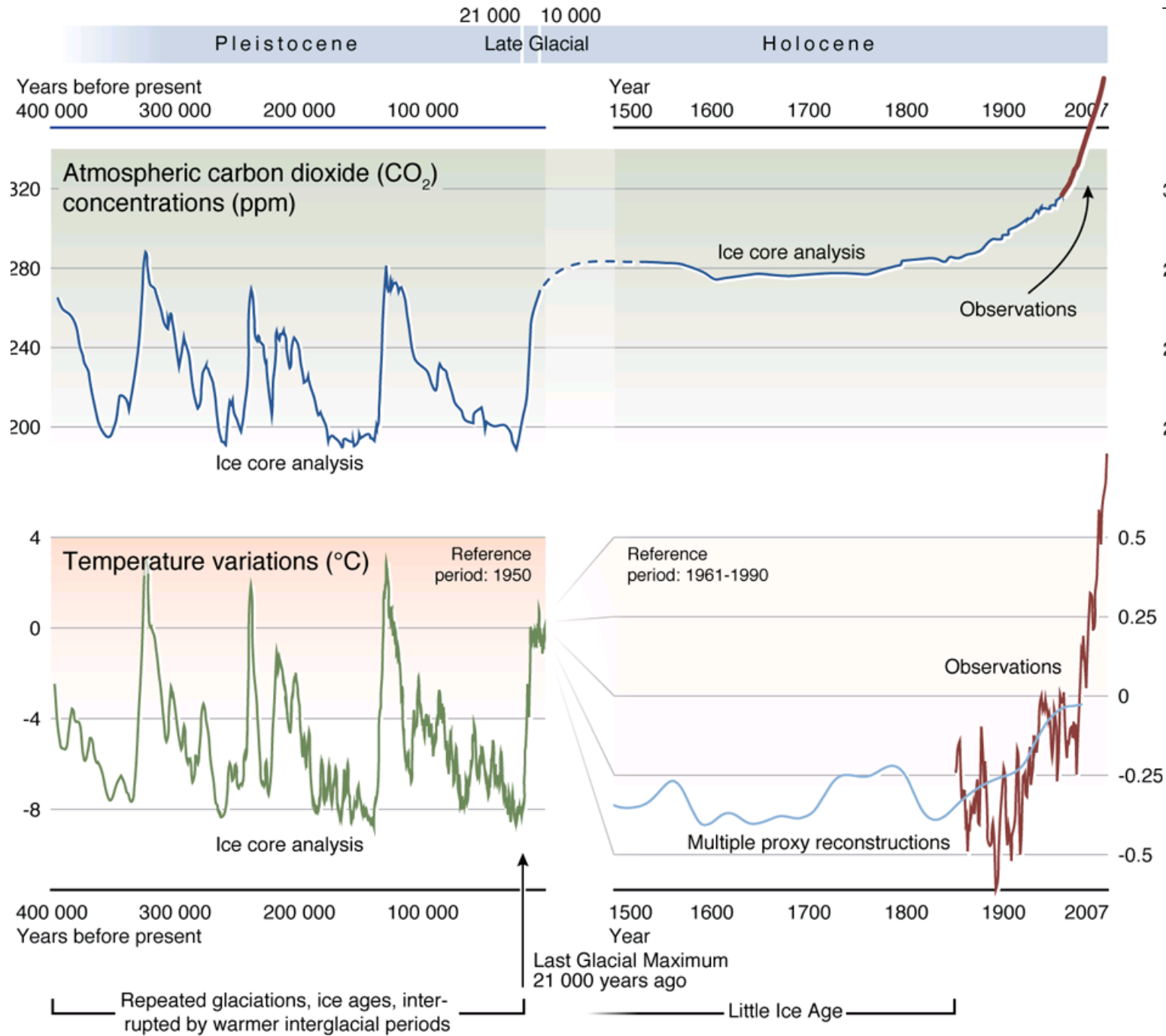
<https://www.slideshare.net/sercuser/still-the-biggest-control-knob-carbon-dioxide-in-earths-climate-history>

# Atmospheric CO<sub>2</sub> (ppm)

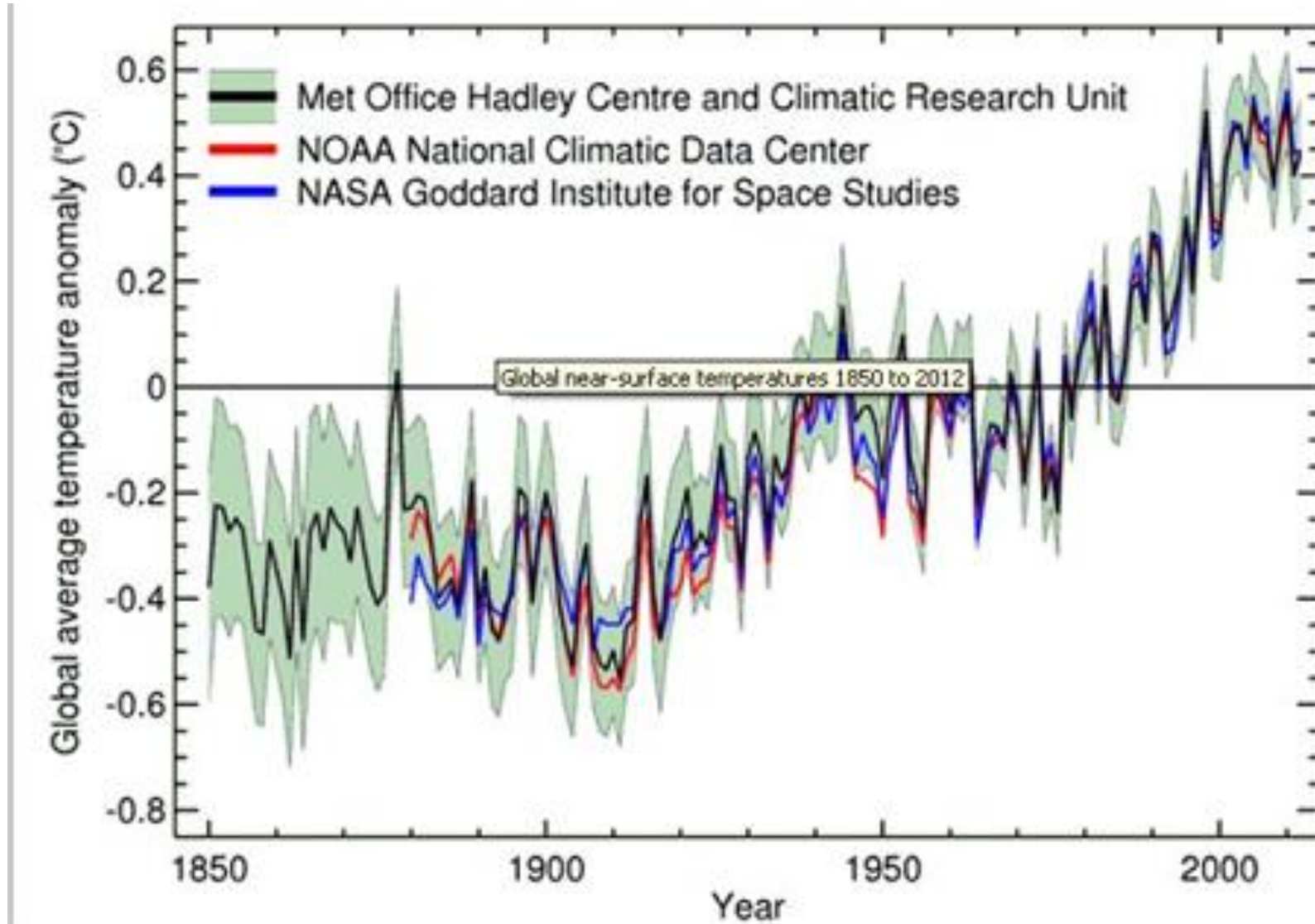
GLOBALVIEW-CO<sub>2</sub> (1979–2008); <http://www.esrl.noaa.gov/gmd/ccgg/globalview/>

● Mauna Loa ● South Pole ● Background conditions ● Local signals  
Contact: andy.jacobson@noaa.gov

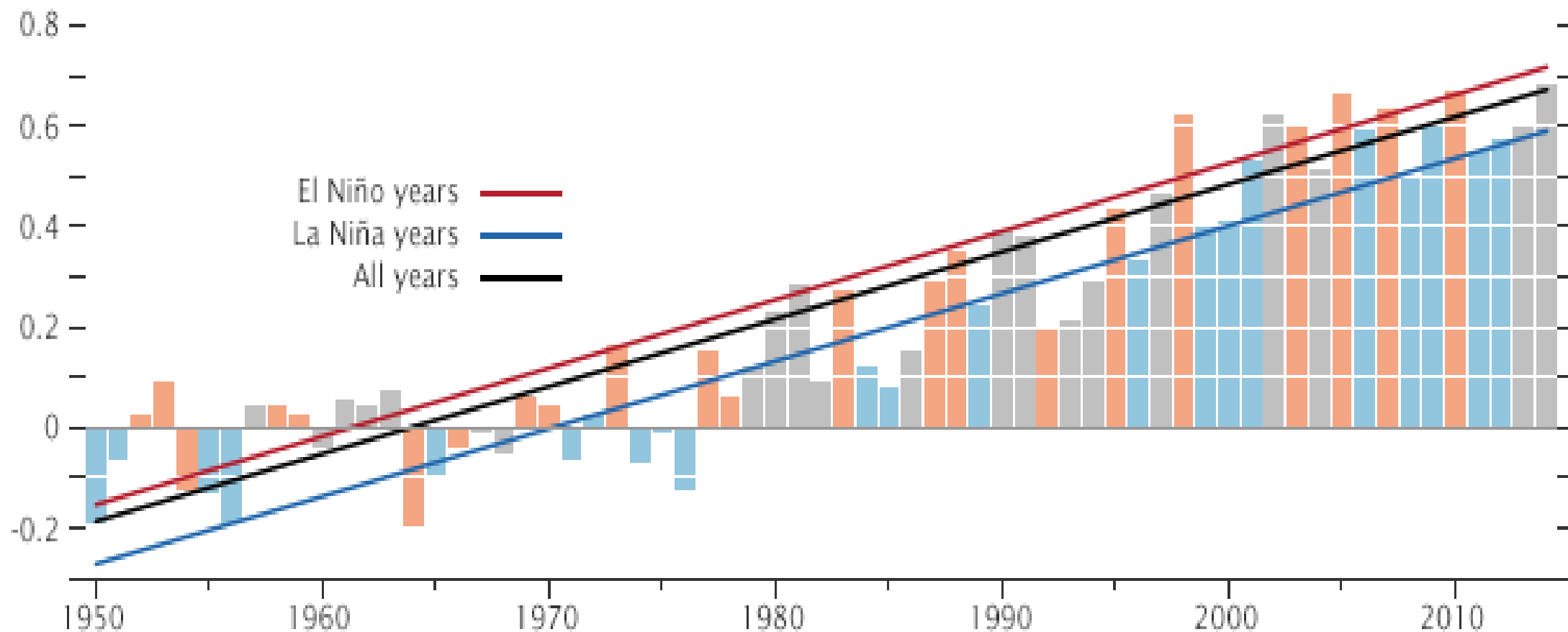




# Average global T increase since 1850



Annual Temperature vs. 1951-1980 Average (°C)

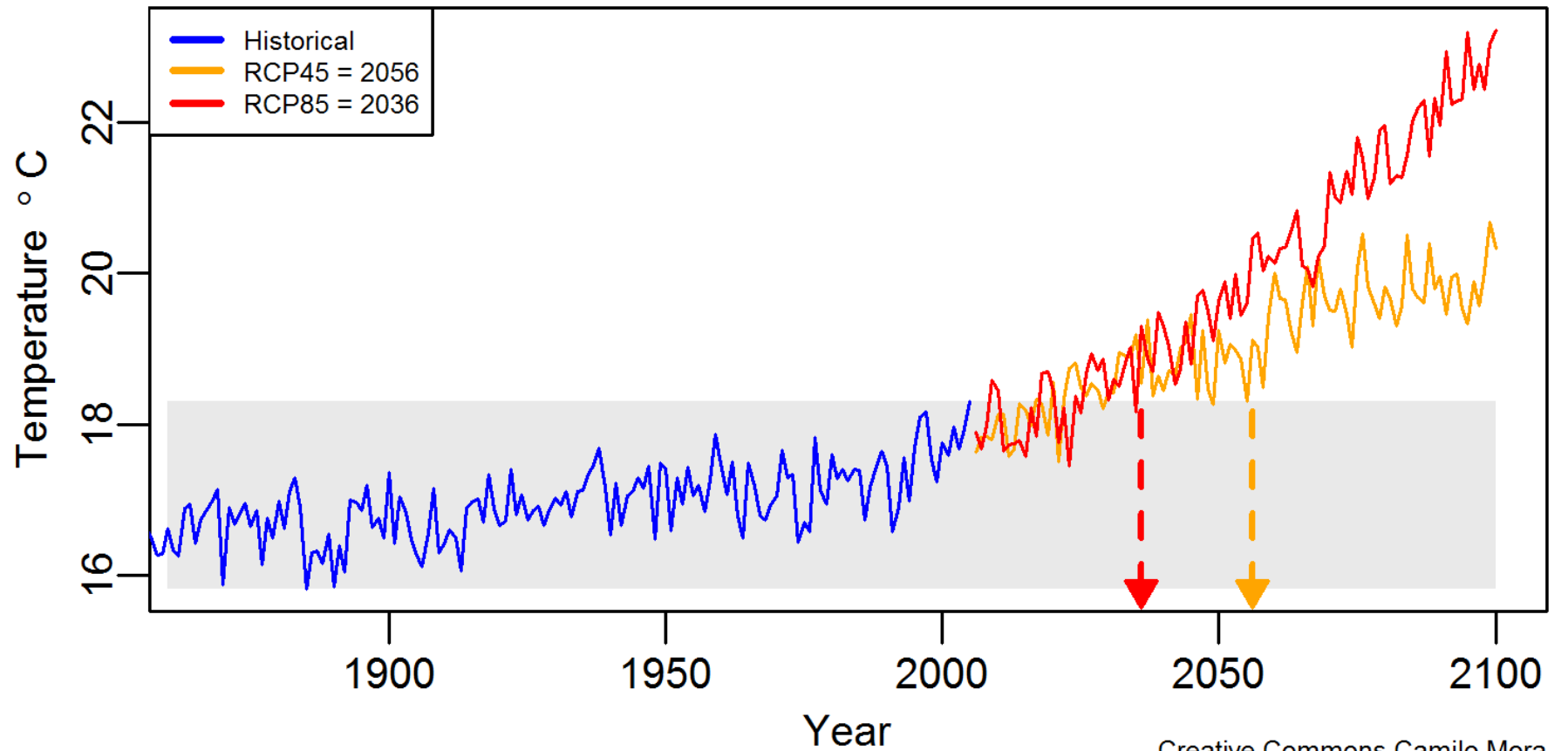


## RCP85

Business as Usual  
Emission of CO<sub>2</sub>

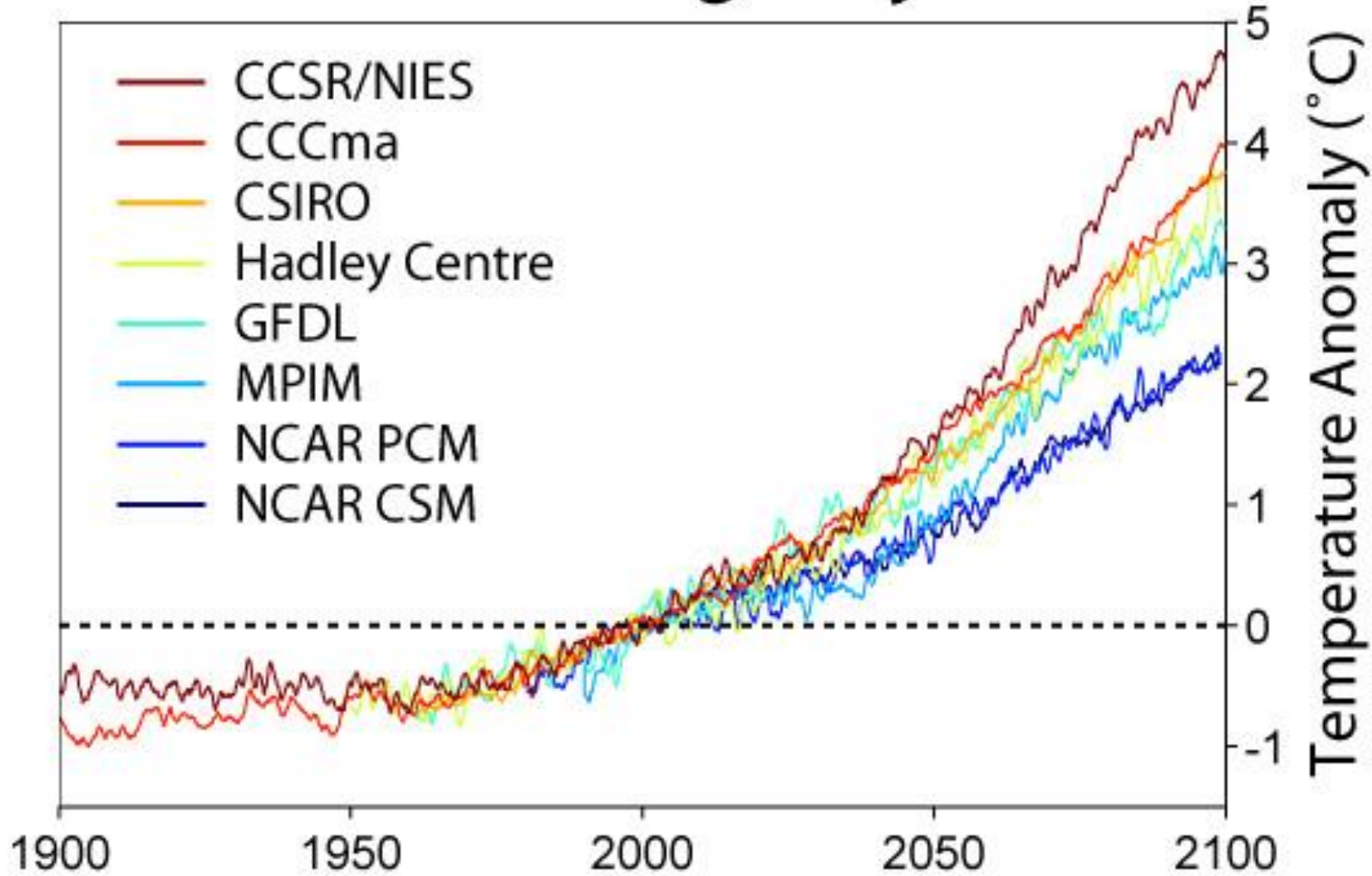
## RCP45

Aggressive Reduction  
in Emission of CO<sub>2</sub>



Marked: “climate departure” ... when *the lowest temperature for a given month will be higher than any temperatures ... experienced over the last 150 years.*

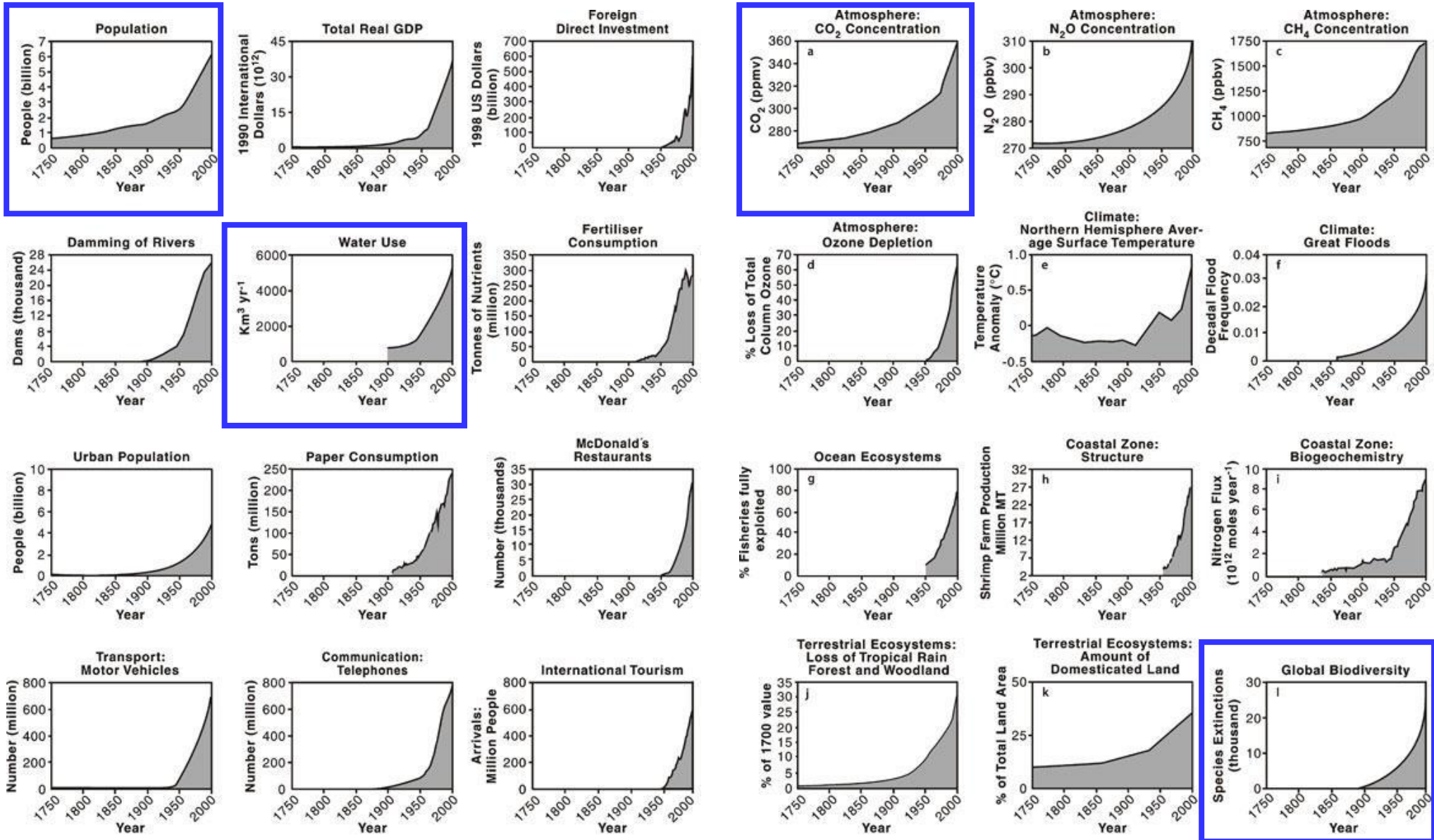
# Global Warming Projections



**Notice the upwards slope of every model by the year 2100.**



# Why so much growth? Population & “Development”



# United Nation's Intergovernmental Panel on Climate Change (IPCC) Reports (Consensus of Thousands of Experts)

“Anthropogenic (*Human Caused*) greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers (*Human factors*), have been detected throughout the climate system and are extremely likely (*95% confidence*) to have been the dominant cause of the observed warming since the mid-20th century.”

“Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks.”

(IPCC, Climate Change 2014 Synthesis Report)

<https://www.ipcc.ch/>

## (United States) FOURTH NATIONAL CLIMATE ASSESSMENT (2017-2018)

**The impacts of climate change are already being felt in communities across the country.** More frequent and intense extreme weather and climate-related events, as well as changes in average climate conditions, are expected to continue to damage infrastructure, ecosystems, and social systems that provide essential benefits to communities. Future climate change is expected to further disrupt many areas of life, exacerbating existing challenges to prosperity posed by aging and deteriorating infrastructure, stressed ecosystems, and economic inequality. Impacts within and across regions will not be distributed equally. People who are already vulnerable, including lower-income and other marginalized communities, have lower capacity to prepare for and cope with extreme weather and climate-related events and are expected to experience greater impacts. Prioritizing adaptation actions for the most vulnerable populations would contribute to a more equitable future within and across communities. Global action to significantly cut greenhouse gas emissions can substantially reduce climate-related risks and increase opportunities for these populations in the longer term.

<https://nca2018.globalchange.gov/chapter/front-matter-about/>

# Some reasons to be optimistic

- Human societies, especially with advance notice, can be quite adaptable (though wild plants and animals not so much)
- People are creative and have managed to deal with some global problems in the past (e.g. DDT, CFC's -> ozone hole, etc.)
- Enough technology already exists to address this problem (but the will to act aggressively enough is not yet sufficient)
- The price of solar installations has fallen faster than expected and efficiency of solar panels is improving quickly
- New technologies are being developed that will be brought to bear in coming years (but when & actual effectiveness TBD)

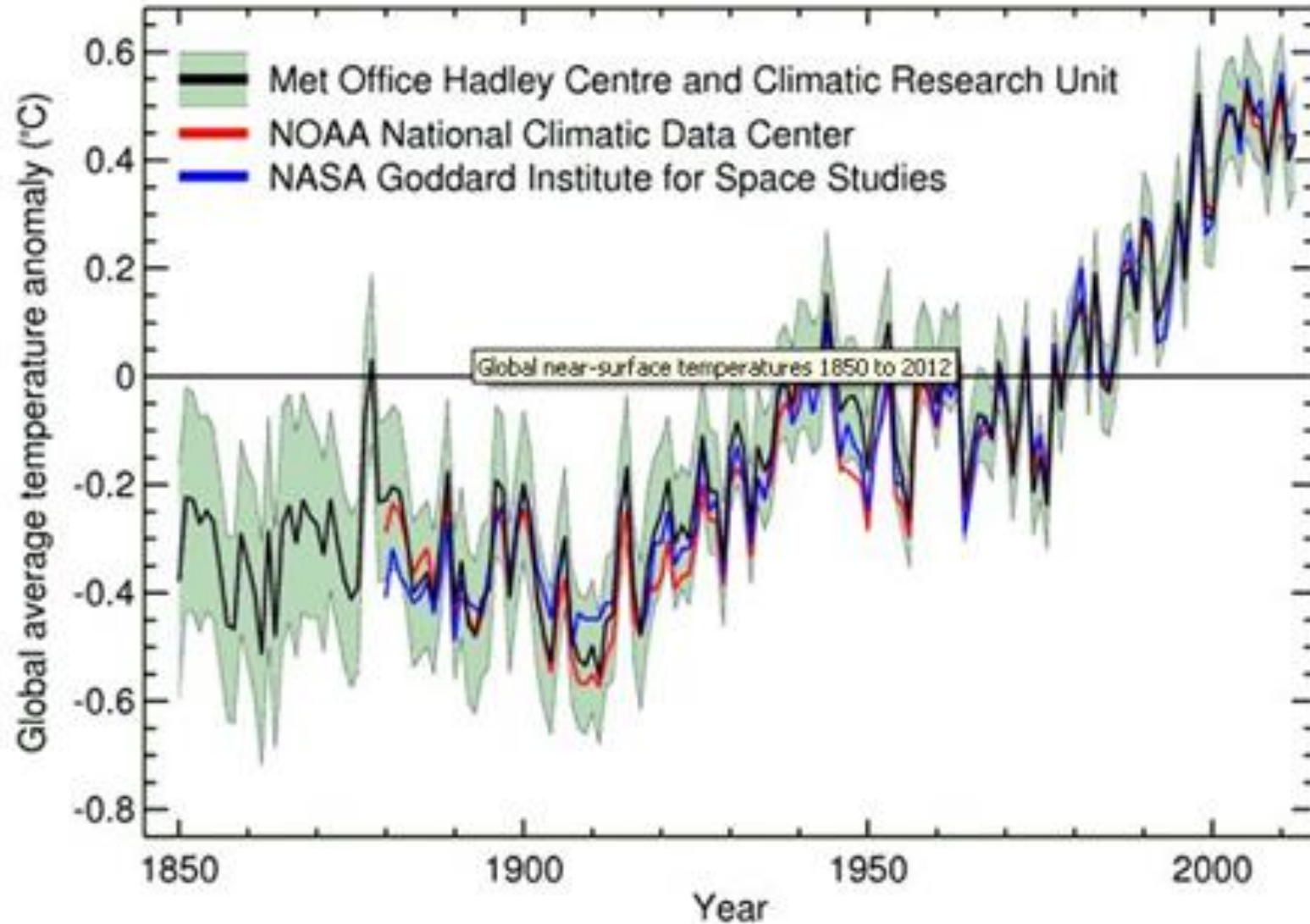
# Some reasons to be pessimistic

- This problem is much more pernicious than previous ones
- The countries most responsible for the problem, and most able to help address it, are often the countries least impacted (and hence, sometimes, the least motivated to act)
- Conventional “nation development” increases emissions
- Many “solutions” just defer (and complicate) matters
- It might not be possible to act quickly enough to get ahead of this problem -> there are many positive feedback loops
- Solutions are expensive (but people are realizing that not solving this problem is even more expensive)

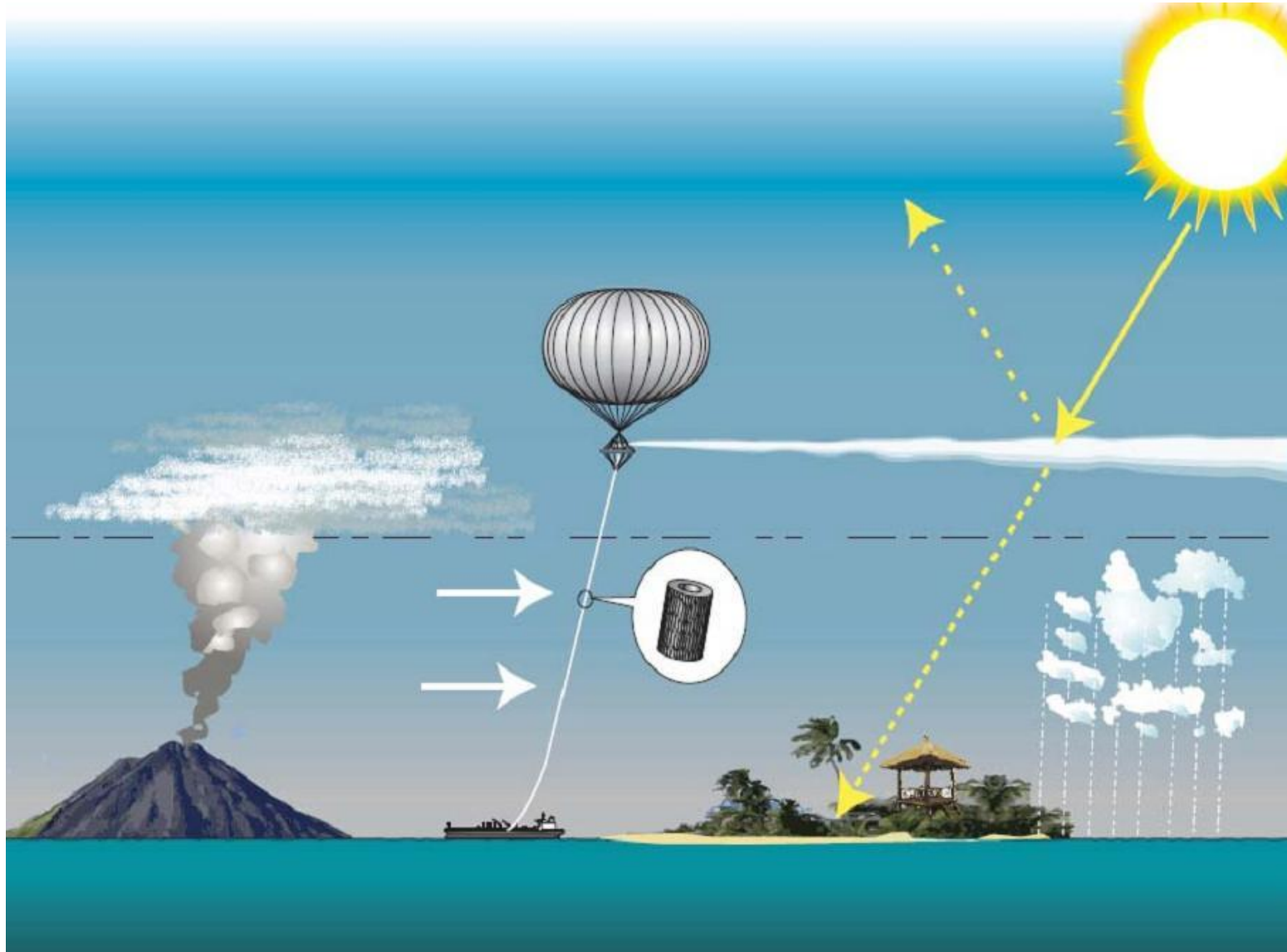
# Some pathways and feedback loops



# Why the “pause” in global warming?



# Solar Geo-Engineering (AKA Solar radiation management)



[https://en.wikipedia.org/wiki/Solar\\_radiation\\_management](https://en.wikipedia.org/wiki/Solar_radiation_management)



# More take-aways

Every realistic/comprehensive plan to mitigate global warming requires steep cuts (starting now!) in emissions of greenhouse gases (esp. CO<sub>2</sub>)

Reducing greenhouse gas emissions may be hard, but actively getting CO<sub>2</sub> out of the atmosphere is harder still so don't count on that (much).

Beware also of betting on untested technologies; expect failures & unintended consequences.

No silver bullet, but lots of silver buckshot.

# Good news / Bad news

Despite its complexity,  
we now have a good understanding  
of the Earth's climate system

Understanding the system  
has not resulted in adequate  
will to fix this problem (yet).

# Good news / Bad news

Some places on Earth  
might appear to gain some benefits  
from global warming.

Global climate change (including  
more extreme weather events)  
is having a net-negative effect on  
essentially all places on Earth.

# Good news / Bad news

Some progress has been made at the international level to reduce greenhouse gas emissions.

Countries aren't living up to the promises they made in the Paris Agreement (and that was not sufficient to limit warming to  $<2^{\circ}$  C anyway).

# Good news / Bad news

**There are many options for energy production without greenhouse gas emissions.**

**Fossil fuels are inexpensive, convenient, and their proponents have a strong lobby – they aren't going away any time soon.**

# Good news / Bad news

Plants naturally take CO<sub>2</sub> out of the atmosphere and sequester the carbon.

Burning plants (fossil fuels are made from plants), or just letting them decay naturally, allows the carbon to re-enter the atmosphere.

# Good news / Bad news

Climate change takes time and things aren't intolerable yet (here), so we have time to continue to act.

The impact of CO<sub>2</sub> is cumulative – the Earth will continue to warm (and will stay warm) even if CO<sub>2</sub> emissions were to be halted now.

**Actual news (i.e. Current Events)**





**Greta Thunberg in New York City**

**Youth hold climate strikes worldwide on Sept. 20, 2019**

<https://www.cnn.com/2019/09/20/world/gallery/climate-strike-2019/index.html>



**Brussels, Belgium**

**Youth hold climate strikes worldwide on Sept. 20, 2019**

<https://www.cnn.com/2019/09/20/world/gallery/climate-strike-2019/index.html>



**Youth hold climate strikes worldwide on Sept. 20, 2019**

<https://www.cnn.com/2019/09/20/world/gallery/climate-strike-2019/index.html>



**Lahore, Pakistan**

**Youth hold climate strikes worldwide on Sept. 20, 2019**

<https://www.cnn.com/2019/09/20/world/gallery/climate-strike-2019/index.html>



**Johannesburg, South Africa**

**Youth hold climate strikes worldwide on Sept. 20, 2019**

<https://www.cnn.com/2019/09/20/world/gallery/climate-strike-2019/index.html>



# Youth hold climate strikes worldwide on Sept. 20, 2019

<https://www.twincities.com/2019/09/20/youth-climate-strike-draws-thousands-across-minnesota/>



## **Greta Thunberg, age 16, climate activist at Climate Action Summit, Sept. 23, 2019**

<https://www.theguardian.com/environment/video/2019/sep/23/greta-thunberg-to-world-leaders-how-dare-you-you-have-stolen-my-dreams-and-my-childhood-video>

**Minnesota news**



# MN state government plans

## Walz unveils plan for all carbon-free electricity by 2050

Elizabeth Dunbar and Cody Nelson St. Paul March 4, 2019 9:39 a.m.



Gov. Tim Walz gestures to renewable energy workers during a press conference announcing a plan to make Minnesota's electric energy carbon-free by 2050 inside the Minnesota State Capitol on Monday. ■ Evan Frost | MPR News



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- Twin Cities mosque on edge after opponents start pointing the cameras at children
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- Bombas vs. Bombers: Here's why Twins-Yankees series will be like no other



# Xcel Energy plans



Billing &  
Payment

Start, Stop,  
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Programs &  
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Outage &  
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## Building a Carbon-Free Future

Our bold vision for 2030 and 2050.

100% carbon free by 2050 and 80% less carbon by 2030.

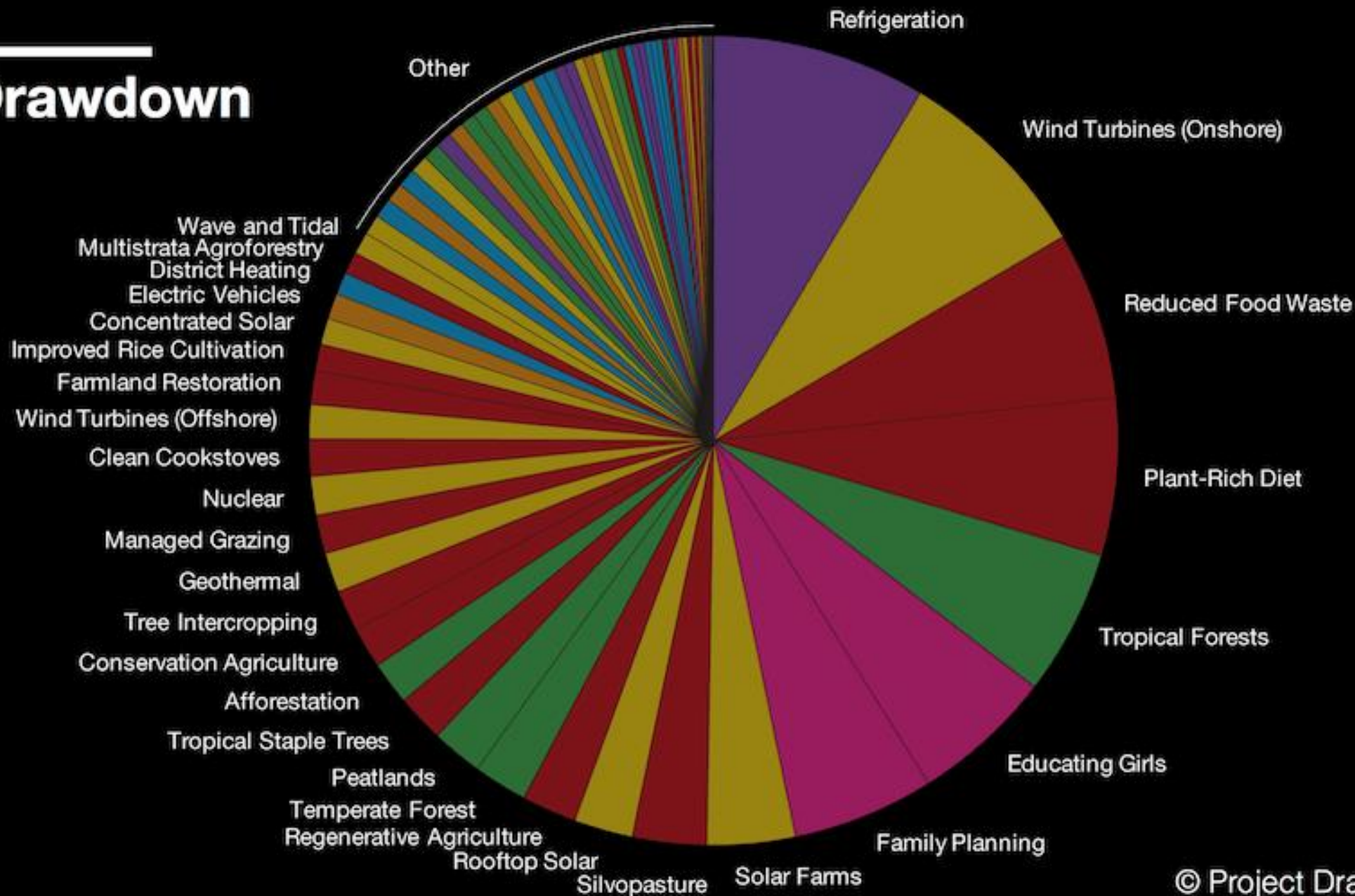
[https://www.xcelenergy.com/environment/carbon\\_reduction\\_plan](https://www.xcelenergy.com/environment/carbon_reduction_plan)

**What to do**

# What can be done (globally)?

- Reduce emissions of greenhouse gases
  - Use less energy; increase energy efficiency
  - Renewable energy sources (wind, solar, waves)
  - Reduce burning of fossil fuels (esp. coal & oil)
- Carbon capture & sequestration
- Educate people (especially women/girls)
  - Family planning, better farming practices, etc.
- Changes to land management & the food system
  - Eat local & lower on the food chain; waste less

# Drawdown



# 100 SOLUTIONS TO REVERSE GLOBAL WARMING

RANKED BY IMPACT

[drawdown.org](http://drawdown.org)

© Project Drawdown, 2017

The video player shows a man, Chad Frischmann, presenting a large circular chart with 100 colored segments. The chart is titled 'Drawdown' and lists various solutions to global warming. The solutions listed include: Refrigeration, Wind Turbines, Ostrich, Reduced Food Waste, Meat Red Diet, Tropical Forests, Improved Rice C, Farmland, Nuclear, Coal, Electric, Concentrate, and Wind. A large white play button is centered over the chart. The video title '100 solutions to reverse global warming' is displayed at the bottom of the video frame. The speaker's name 'Chad Frischmann | We the Future' is also visible. The video player includes a progress bar, a timestamp of 16:55, and icons for volume, comments, settings, and full screen. On the right side of the player, there are social sharing and interaction icons: Share, Add to list, Like, and Recommend.

[https://www.ted.com/talks/chad\\_frischmann\\_100\\_solutions\\_to\\_climate\\_change](https://www.ted.com/talks/chad_frischmann_100_solutions_to_climate_change)

NEW YORK TIMES BESTSELLER

# DRAWDOWN

THE MOST COMPREHENSIVE  
PLAN EVER PROPOSED TO  
REVERSE GLOBAL WARMING  
EDITED BY PAUL HAWKEN



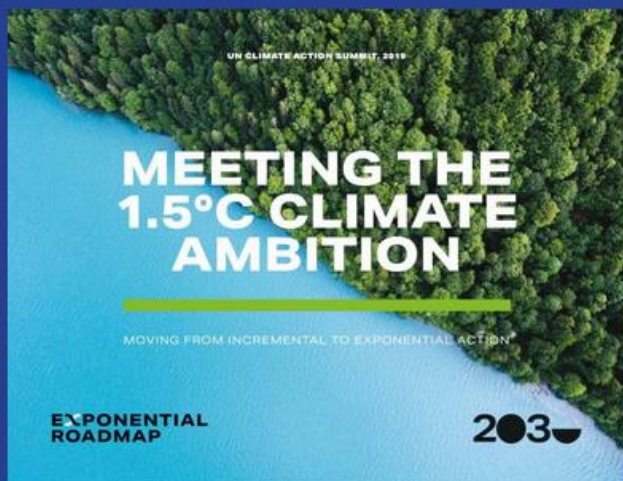
#1 Best-Selling Environmental Book of 2017

ORDER THE BOOK

“...read this book — not just as an antidote to fear and despair but as foundation for understanding.”

— Ron Meador, MinnPost

MORE REVIEWS



Just released: The 2019 Exponential Roadmap shows how to accelerate 36 solutions to reduce greenhouse gas emissions 50% by 2030.

GET THE ROADMAP

<https://www.drawdown.org/>

# What can be done (personally)?

- Learn even more – e.g. books, TED talks, lectures
- Talk about Global Warming and Climate Change
- Consider both when making personal decisions
  - What to buy, how to get around
  - What people & causes to support / vote for
- Act to enable “global” solutions when you can
  - Energy: increase efficiency, use renewables
  - Farming & food: waste less, eat less meat



**Don't get discouraged; be hopeful, but persistent**

**Do what you can,  
when you can,  
as often as you can.**



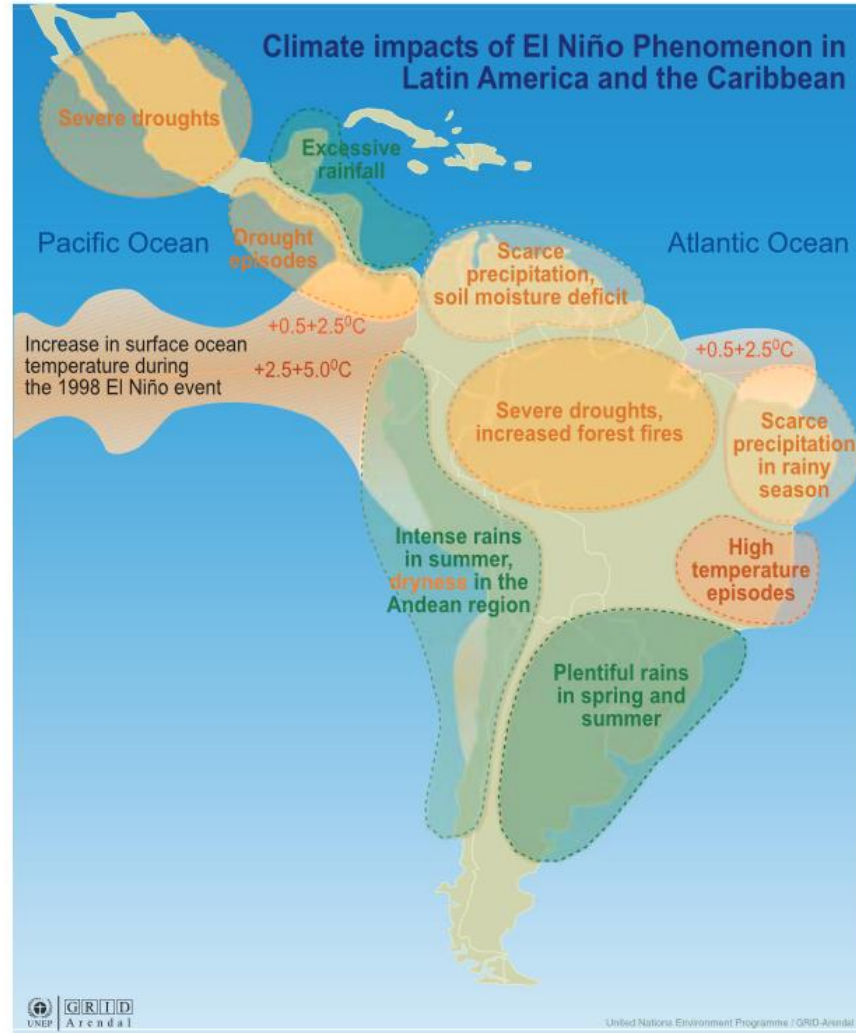


Broadcast in May 2014



# Some consequences of Global Warming

FIGURE A.8 Climate Impacts of El Niño in the LCR Region



Source: Modified from UNEP GRID Arendal.  
Note: The figure shows the climate impacts of the El Niño-Southern Oscillation phenomenon. LCR = Latin America and Caribbean region.

Global  
Climate  
Change

- Polar ice melting
- Sea level rise
- Extreme weather (more strong storms, wild fires, floods, and severe droughts)
- Agricultural issues
- Spread of diseases
- Loss of biodiversity

# Consequences contd: “a threat multiplier”

- Access to clean water reduced
- Ability to reliably grow food reduced
- Increasing numbers of climate migrants
- Economic impacts, especially to the poor
- Increasing rates of poverty
- Induced social/political instability
- Negative impacts on human health
- Wide disparities in vulnerability (& culpability)