

Insights from Climate Science Or Why the Wafflers are Wrong

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**Lecture for the HKS Executive Program on
Climate Change and Energy
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Coverage of the lecture

- Fundamentals of global climate change (CC)
- Categorizing contrarian confusion-mongering
 - Denial
 - Waffling
 - Surrender
- Rebutting denial: How we know CC is real
- Rebutting waffling: How we know CC is urgent
- Rejecting surrender: How we know addressing CC is worth the effort

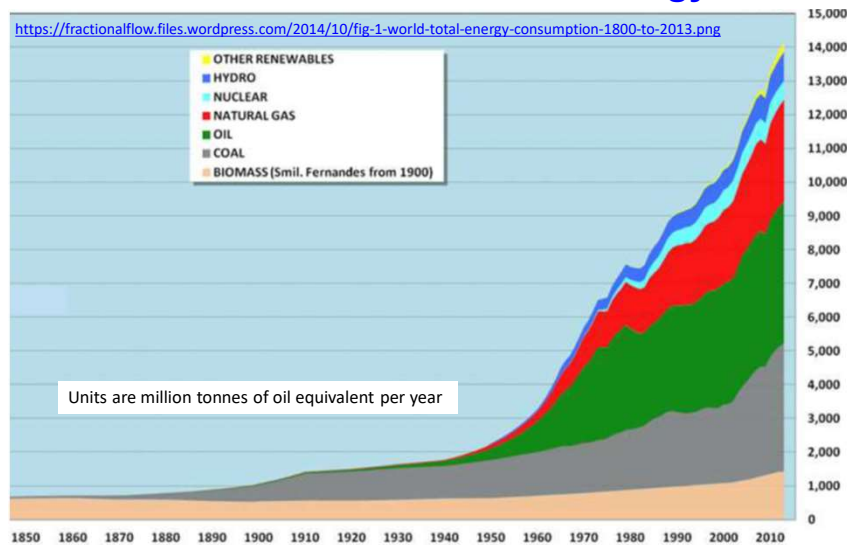
Fundamentals

“Everyone is entitled to his own opinion, but not his own facts.”

Daniel Patrick Moynihan

Fundamentals of climate change

Growth of world population & prosperity from 1850 to 2015 led to a 22-fold increase in energy use.



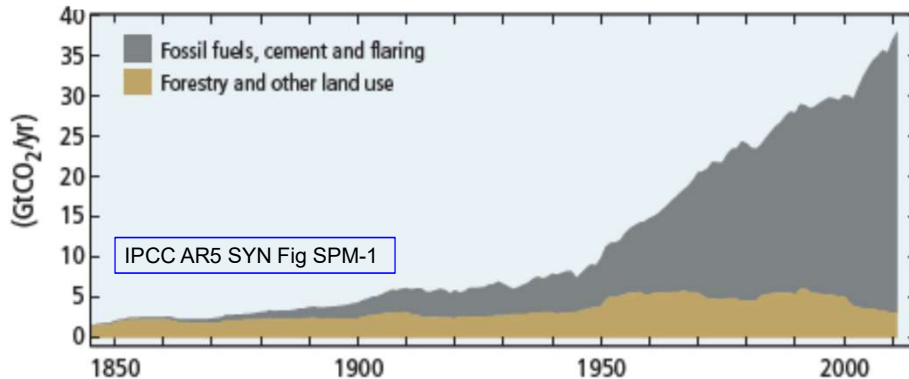
In 2015 the world still depended on coal, oil, & natural gas for about 80% of its total energy supply and two-thirds of its electricity.

Fundamentals of climate change

Civilization's CO₂ emissions tracked the rise of fossil-fuel use & deforestation

Roughly, coal is CH, oil is CH₂, natural gas is CH₄, and wood is CH₂O. In each case, their combustion produces CO₂ and H₂O, all going into the atmosphere.

Global anthropogenic CO₂ emissions



The H₂O stays in the atmosphere only briefly, so the additions do not accumulate there. But much of the CO₂ stays long and accumulates.

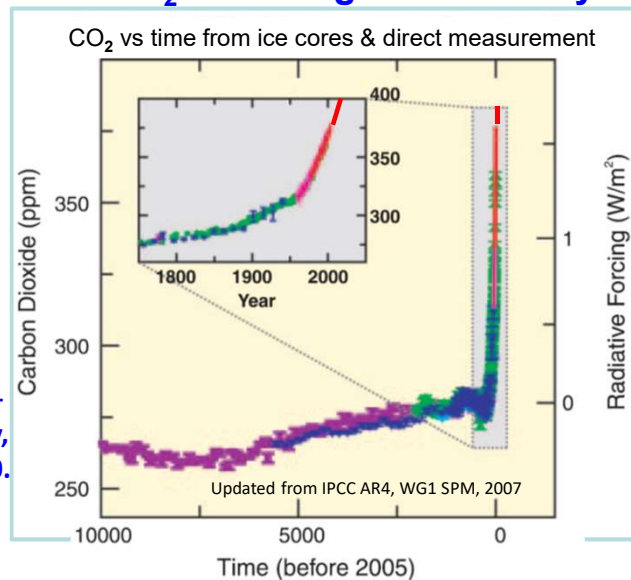
Fundamentals of climate change

So the atmosphere's CO₂ content grew markedly

The record of CO₂ content over the millennia (from ice cores, large curve) shows the gradual rise from the Agricultural Revolution and the steep rise from the Industrial Revolution.

The 2017 CO₂ concentration was 407 ppmv, 46% higher than 1750.

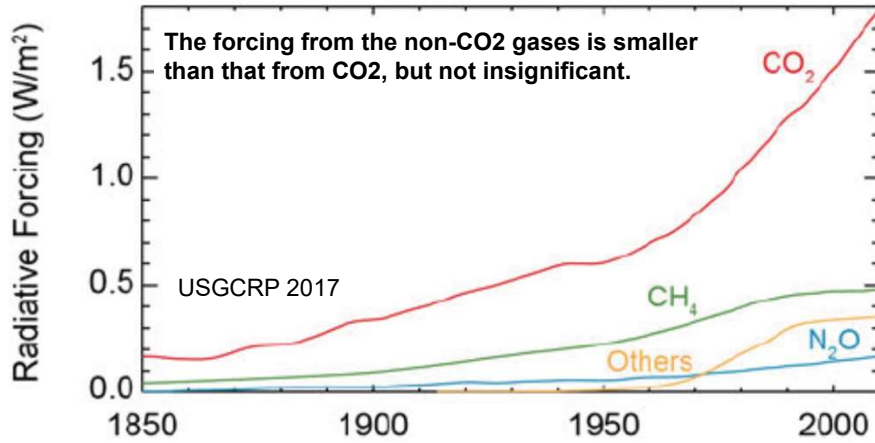
The "forcing" (scale on the right) is the resulting change in the energy balance of the atmosphere since 1750.



Fundamentals of climate change

Humans have added other heat-trapping gases too

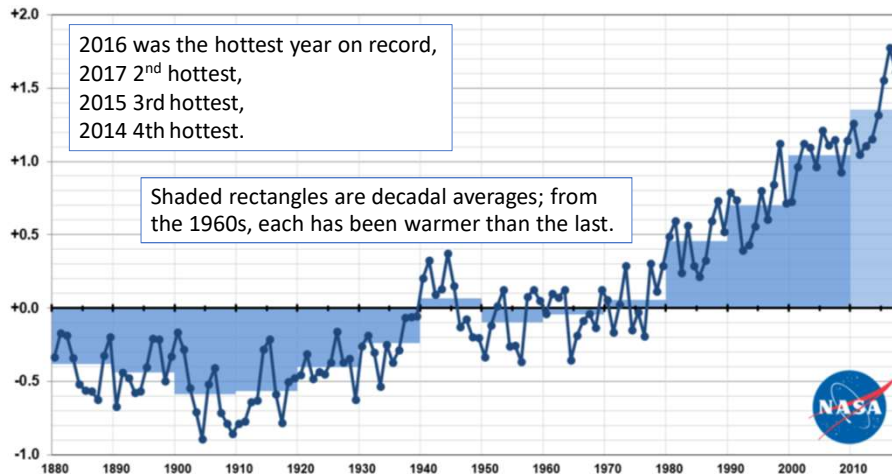
Most important are methane (CH₄) & nitrous oxide (N₂O) from energy systems & agriculture and (most recently) CFCs & HFCs from consumer products & industry



Fundamentals of climate change

Global-average surface air temperature 1880-2017

Annual Global Temperature: Difference From 1951-80 Average, in °F



Earth has been warming more or less steadily for the last 100+ years, as the increasing forcing from the human-caused GHG buildup came to dominate natural variability.

Fundamentals of climate change

But “global warming” is something of a misnomer

That term implies something...

- uniform across the planet,
- mainly about temperature,
- gradual,
- quite possibly benign.

This seems to have confused people.

What’s actually happening is...

- highly nonuniform,
- not just about temperature,
- rapid compared to capacities for adjustment
- harmful for most places and times

A more descriptive term is “global climate disruption”.

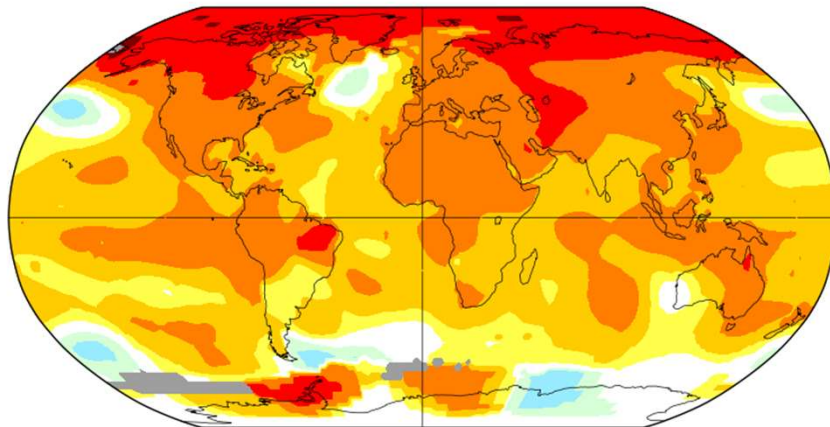
Fundamentals of climate change

The T change is highly non-uniform

Annual J-D 2016

L-OTI(°C) Anomaly vs 1951-1980

0.98



-4.1 -4.0 -2.0 -1.0 -0.5 -0.2 0.2 0.5 1.0 2.0 4.0 4.1 NASA

Uneven T change → changes in atmospheric & ocean circulation.

Fundamentals of human-caused climate change

The changes are not just about temperature.

Climate = weather patterns, meaning averages, extremes, timing, and spatial distribution of...

- yes, hot & cold, but also...
- cloudy & clear
- humid & dry
- drizzles, downpours, & hail
- snowfall, snowpack, & snowmelt
- breezes, blizzards, tornadoes, & typhoons

Climate change entails disruption of the patterns.

Global average T is just an index of the state of the global climate system as expressed in these patterns. Small changes in the index correspond to big changes in the system (much like your body temperature).

Fundamentals of human-caused climate change

These changes matter because...

Climate governs (so altering climate affects)

- availability of water
- productivity of farms, forests, & fisheries
- prevalence of oppressive heat & humidity
- formation & dispersion of air pollutants
- geography of disease
- damages from storms, floods, droughts, wildfires
- property losses from sea-level rise
- expenditures on engineered environments
- distribution & abundance of species

Categorizing Contrarian Confusion-Mongering

“A lie gets halfway around the world before the truth can
get its boots on.”

Mark Twain

Categorizing contrarian confusions

Classes of contrarian arguments

Type 1: “The Earth isn’t really warming.”

Type 2: “It’s warming, but humans have nothing to do with it.”

Type 3: “Humans may have something to do with it, but...

3.a ...“we don’t know how much,” or

3.b ...“it doesn’t matter because it’s a good thing,” or

3.c ... “it’s slow so we have plenty of time to adapt,” or

3.d ... “we’re better off investing in economic development
than addressing climate change directly.”

Type 4: “Yes, the human role is large and dangerous, and
development alone is inadequate protection, but it’s too
late (or too costly) to fix it...so let’s just hunker down.”

Categorizing contrarian confusions

Classes of contrarian arguments

Type 1: “The Earth isn’t really warming.”

DENIAL

Type 2: “It’s warming, but humans have nothing to do with it.”

Type 3: “Humans may have something to do with it, but...

3.a ...“we don’t know how much,” or

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3.c ... “it’s slow so we have plenty of time to adapt,” or

3.d ... “we’re better off investing in economic development than addressing climate change directly.”

WAFFLING

Type 4: “Yes, the human role is large and dangerous, and development **SURRENDER** protection, but it’s too late (or too costly) to fix it...so let’s just hunker down.”

SURRENDER

Categorizing contrarian confusions

Among contemporary contrarians, the wafflers are the ones being taken most seriously

- The numbers of deniers are dwindling in the face of ever more obvious climate change that everyone can see and for which no one has offered a plausible alternative to human influence.
- The wafflers are more numerous and seem less unreasonable. They are not denying the obvious, and their arguments are more nuanced than those of the deniers.
- Those suggesting surrender, while slowly increasing in number, are offering an argument of despair that is unpalatable to most who agree that the problem is real.

I’ll offer rebuttals to the arguments of all 3 categories of contrarians but spend the most time on the most dangerous—the wafflers.

Rebutting the Deniers

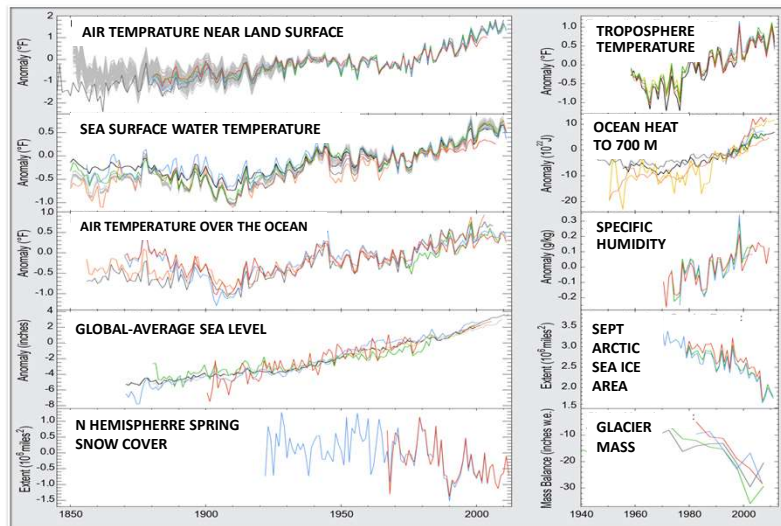
“Science is true whether or not you believe in it.”

Neil deGrasse Tyson

Rebutting the deniers

There is no scientific doubt the world is warming.

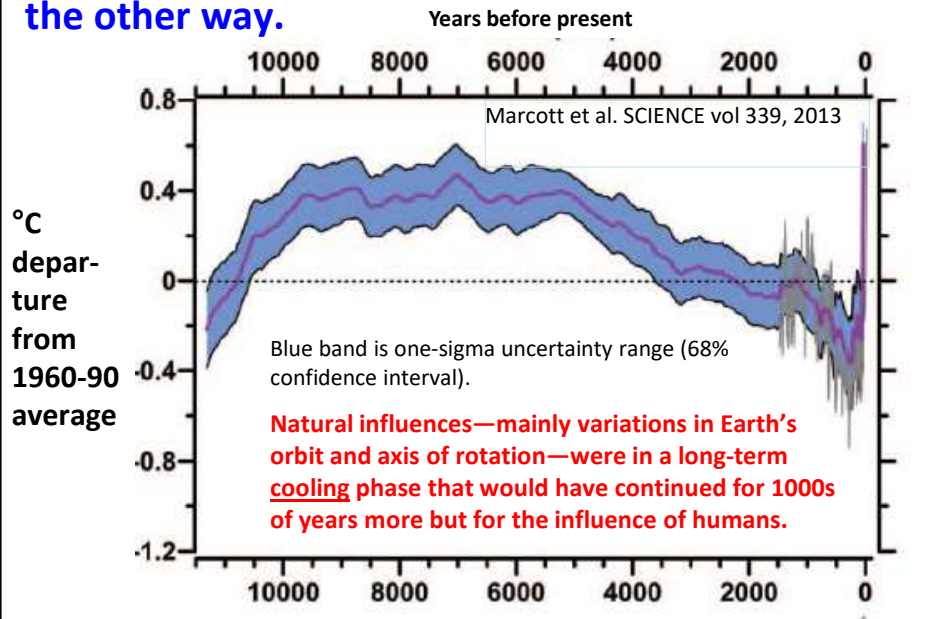
Trends in every relevant indicator are consistent.



IPCC WGI 2013

Rebutting the deniers

Humans are clearly the cause; nature was heading the other way.



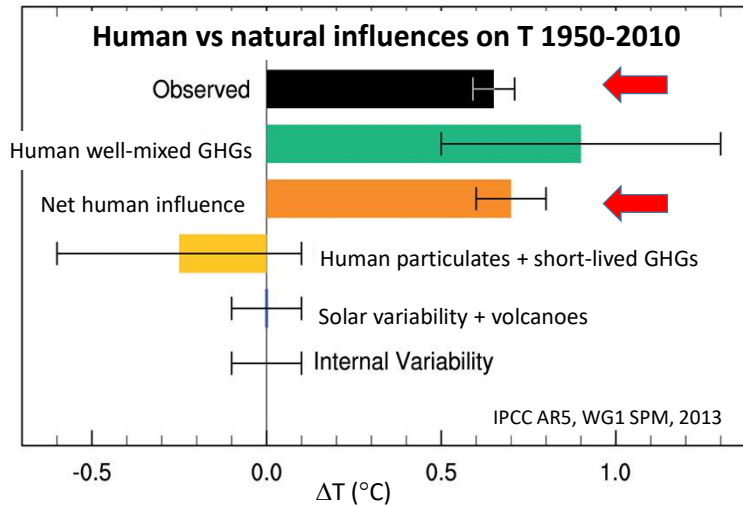
Rebutting the Wafflers

“You may be able to fool the voters, but not the atmosphere.”

Donella Meadows, co-author of Limits to Growth (1971)

Rebutting the Wafflers

We know how much of the warming trend is human-caused: Over the past 60 years, essentially all of it.



The wafflers' claim there's a lot of uncertainty about the human role is wrong.

Rebutting the wafflers

Climate change is already causing growing harm

Around the world we're seeing, variously, increases in

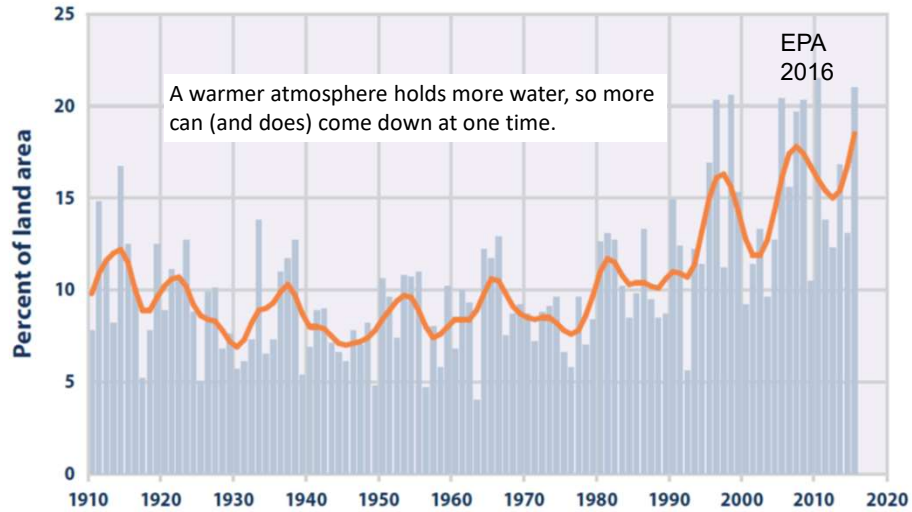
- floods
- drought
- wildfires
- heat waves
- power of strongest storms
- other harm to human health
- impacts of crop & forest pests
- coastal erosion and inundation
- permafrost thawing & subsidence
- impacts of ocean acidification, warming, altered currents, loss of sea ice on distribution/abundance of valued species

All are plausibly linked to climate change by theory, models, and observed "fingerprints"; most growing faster than projected.

Rebutting the wafflers

Growing harm: Torrential downpours → floods

Extreme One-Day Precipitation Events in the Contiguous 48 States, 1910–2015



Rebutting the wafflers

Downpours → Floods (continued)

“Hundred-year” floods now occur once a decade or more in many places.

Three “five-hundred-year” floods occurred in Houston in three years.

East Baton Rouge, LA, August 2016: Up to 20 inches of rain in 3 days

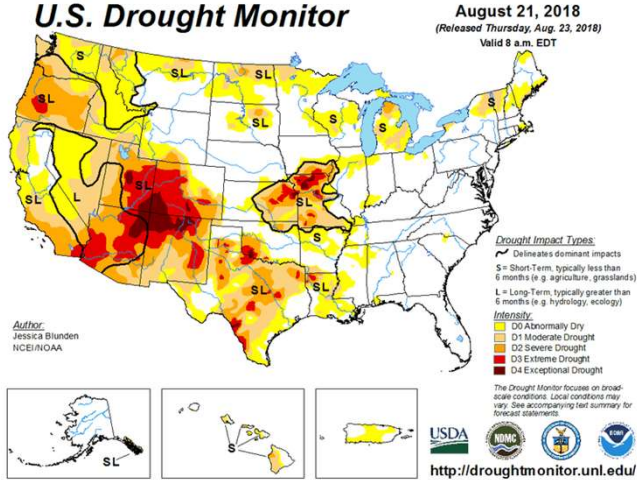


Hurricane Harvey brought >50 inches of rain over 5 days to parts of Texas in August 2017.

Rebutting the wafflers

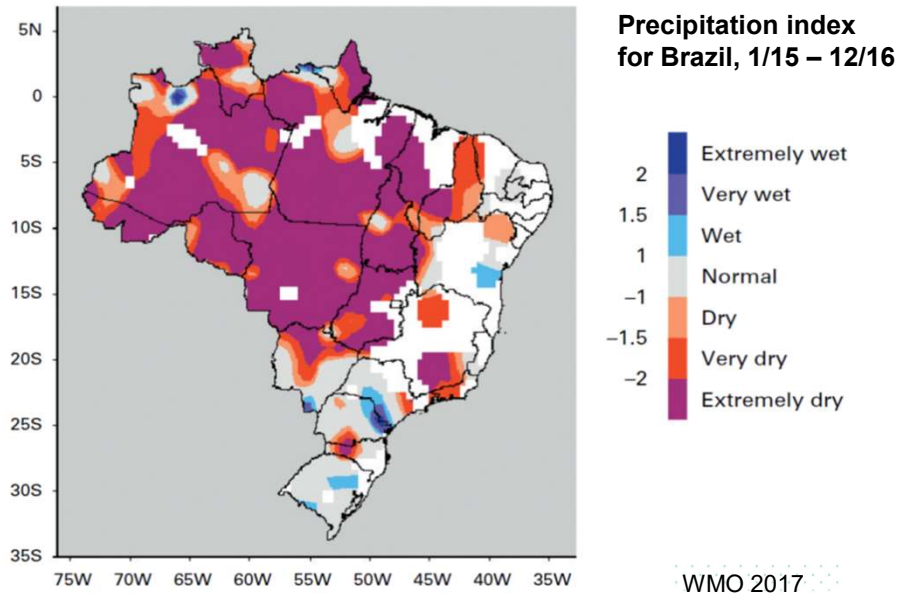
Climate change is exacerbating drought

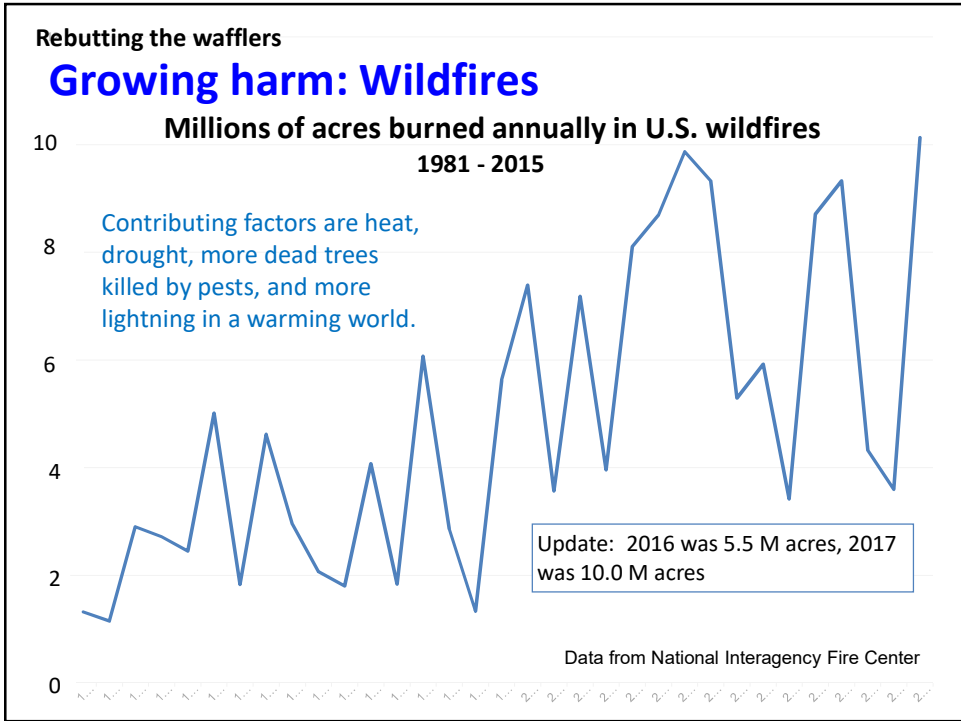
- Higher temperatures = bigger losses to evaporation.
- More of the rain falling in extreme events = more loss to flood runoff, less moisture soaking into soil.
- Mountains get more rain, less snow, yielding more runoff in winter and leaving less for summer.
- Earlier spring snowmelt also leaves less runoff for summer.
- Altered atmospheric circulation patterns also play a role.



Rebutting the wafflers

Growing harm: Drought in the Amazon





Rebutting the wafflers

Wildfires (continued)

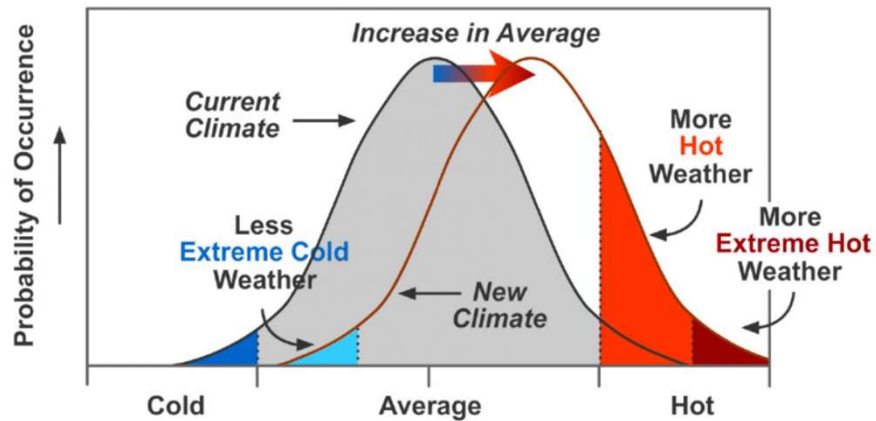
- US fire season ≥ 3 months longer than 40 years ago.
- Average fire much bigger & hotter than before.
- Nine of 10 biggest U.S. wildfires took place since 2004 (the other in 1997).
- Five these were in Alaska, where now even the tundra burns.
- Smoke from today's big fires impacts health 1000s of miles away.

Aniak, AK, June 2015

Wildfire smoke map, created at 5:36 p.m. MDT September 5, 2017. NOAA

Rebutting the wafflers

Growing harm: Modest change in average T has led to enormous change in heat extremes



Thus, in a warmer climate, high-T extremes that previously had probability of occurrence near zero occur with some regularity. This disproportionate impact at the extremes applies to any normally distributed climate-related variable.

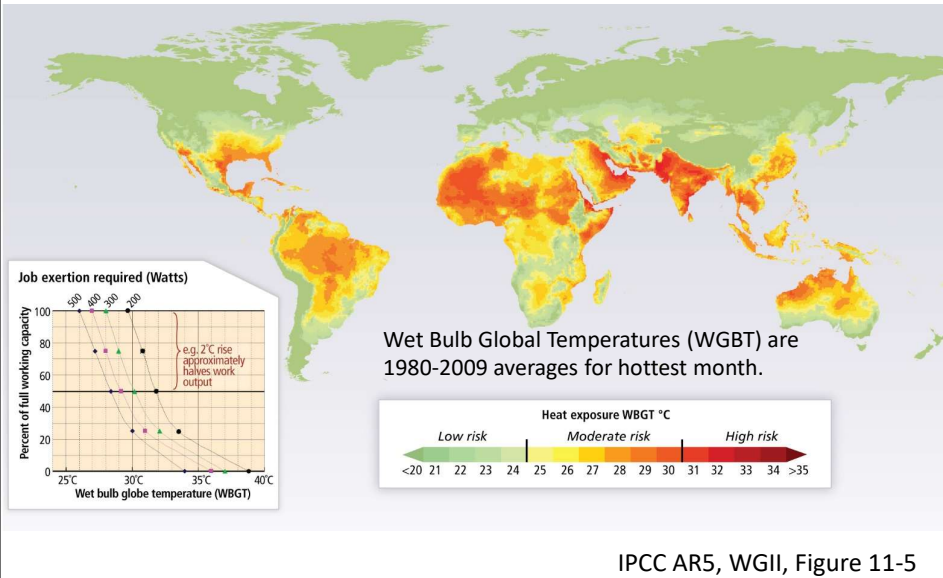
Rebutting the wafflers

Growing harm: Record temps set in 2017-18

• Iran	129°F	June 2017
• Pakistan	128°F	May 2017
• Africa	124°F	July 2018
• Spain	117°F	July 2017
• Chile	113°F	Jan 2017
• Los Angeles	111°F	July 2018
• Argentina	110°F	Jan 2017
• Armenia	108°F	July 2018
• Shanghai	106°F	July 2017
• San Francisco	106°F	Sept 2017
• Denver	105°F	June 2018
• Hong Kong	102°F	Aug 2017
• Scotland	92°F	June 2018

Rebutting the wafflers

Growing harm: Heat already makes working outdoors dangerous in many regions



Rebutting the wafflers

Growing harm: Stronger tropical storms

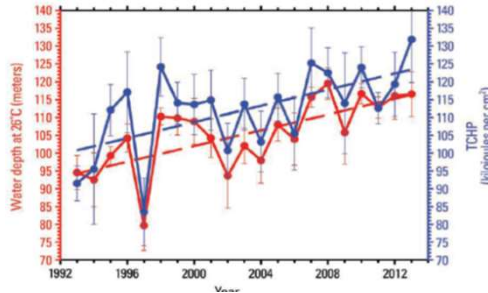
- 10/12: Sandy, largest ever in Atlantic
- 11/13: Haiyan, strongest in N Pacific
- 10/15: Patricia, strongest worldwide
- 10/15: Chapala, strongest to strike Yemen
- 02/16: Winston, strongest in S Pacific
- 04/16: Fantala, strongest in Indian Ocean
- 10/17: Ophelia, strongest in E Atlantic



Rebutting the wafflers

More-devastating cyclones are not coincidence

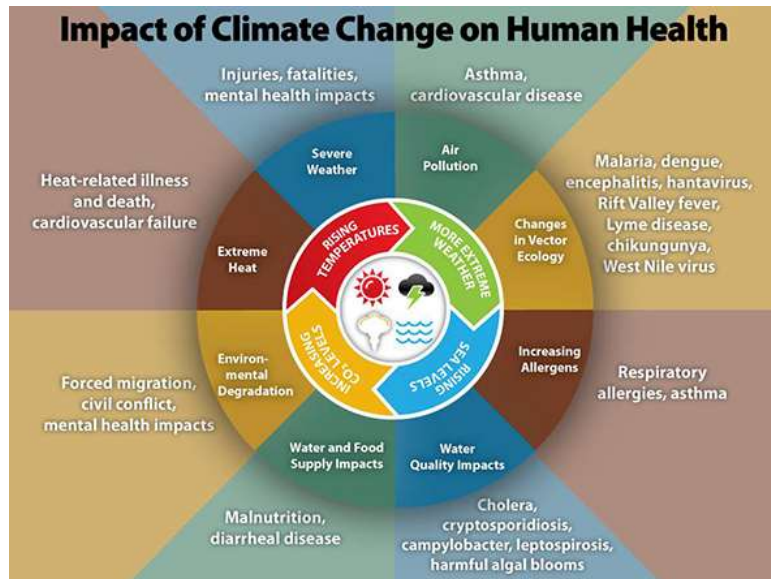
- Tropical cyclones get their energy from the warm surface layer of the ocean (which is getting warmer and deeper under climate change). This means more energy is available for evaporating water from the ocean surface. See figure.
- When the water vapor condenses, it heats the atmosphere. The heated air rises, which lowers pressure at the surface.
- That causes air from surrounding areas to flow inward; the spiral pattern results from Coriolis forces.
- More ocean energy → stronger cyclone; and deeper ocean warm layer means waves churn up less cold water to limit storm's power.
- Many factors affect the formation and tracks of these storms, but, all else equal, a given cyclone will be more powerful in the presence of a warmer ocean with a deeper warm layer than it would be otherwise. And the higher local sea level is, the worse the storm surge from any given cyclone will be.



In the region that spawned Cyclone Haiyan, the Tropical Cyclone Heat Potential had gone up 20% since 1990.

Rebutting the wafflers

Growing harm: Other impacts on human health



Centers for Disease Control & Prevention 2018

Rebutting the wafflers

Growing harm: Impacts of crop & forest pests

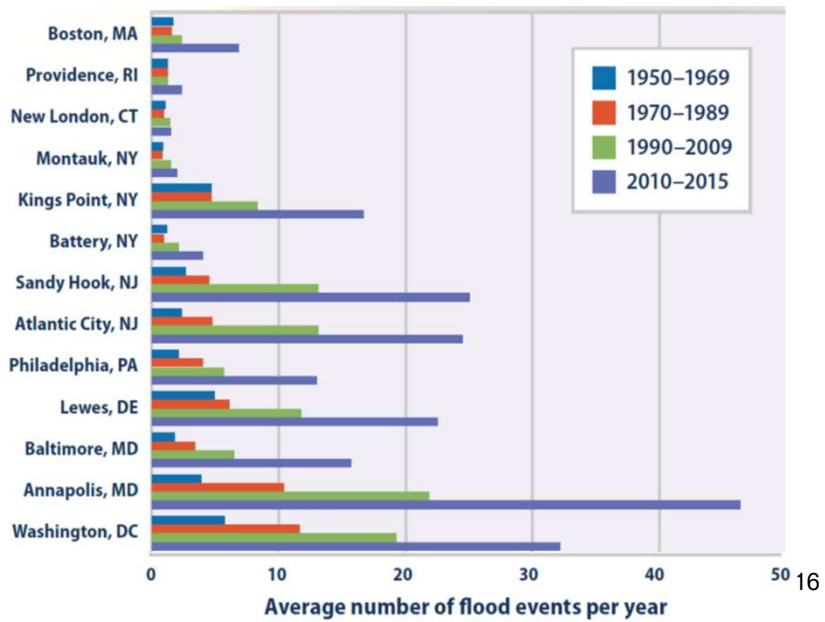
Pine bark beetles, with a longer breeding season courtesy of warming, devastate trees weakened by heat & drought in California, Colorado, Alaska...



USGCRP 2009

Rebutting the wafflers

Growing harm: Rising sea → coastal inundation



Rebutting the wafflers

Growing harm: thawing/subsiding permafrost



Russia



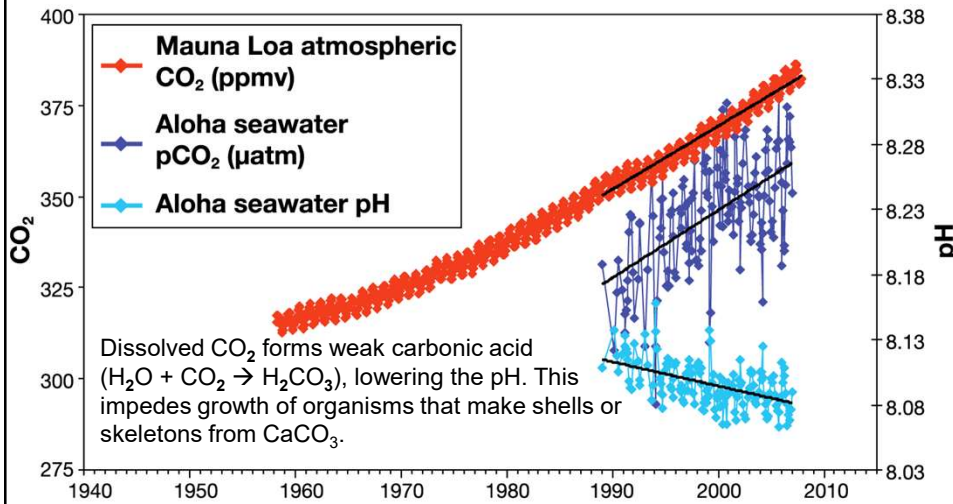
Fairbanks, AK

Norwegian Polar Institute, 2009

Rebutting the wafflers

Growing harm: Ocean acidification & its impacts

About 1/3 of CO₂ added to atmosphere is quickly taken up by the surface layer of the oceans (roughly, the top 80 meters).



World Bank / Potsdam Institute Nov 2012

Rebutting the wafflers

Growing harm: Coral bleaching worldwide



Jarvis Reef, South Pacific (courtesy WHOI)

"As of February 2017, the ongoing global coral bleaching event continues to be the longest and most widespread ever recorded."

https://coralreefwatch.noaa.gov/satellite/analyses_guidance/global_coral_bleaching_2014-17-state.php

Rebutting the wafflers

Growing harm: Other impacts on valued species

Scienceexpress / sciencemag.org/content/early/recent / 29 October 2015

Slow adaptation in the face of rapid warming leads to collapse of the Gulf of Maine cod fishery

Andrew J. Pershing,^{1*} Michael A. Alexander,² Christina M. Hernandez,^{1†} Lisa A. Kerr,¹ Arnault Le Bris,¹ Katherine E. Mills,¹ Janet A. Nye,³ Nicholas R. Record,⁴ Hillary A. Scannell,^{1,5‡} James D. Scott,^{2,6} Graham D. Sherwood,¹ Andrew C. Thomas⁵

PNAS | September 1, 2015 | vol. 112 | no. 35 | 10823–10824

Shifting patterns in Pacific climate, West Coast salmon survival rates, and increased volatility in ecosystem services

Nathan J. Mantua¹

Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Santa Cruz, CA 95060

Rebutting the wafflers

In the face of these observed & growing impacts, the arguments of some wafflers that climate change is “good for us” are revealed as perverse

- Some places may benefit from longer growing seasons, warmer winters, & increased CO₂ fertilization of plants for a few decades, but that can't compensate for all the harms.
 - Longer growing seasons are counteracted by effects of increases in extreme heat, drought, hailstorms, & pests.
 - Many fewer people die of extreme cold in winter than from extreme heat in summer, and the gap is growing.
 - CO₂ fertilization only works for some plants and only when water & other nutrients are in adequate supply. And it's counteracted by heat, drought, storms, & pests.

Wafflers are wrong to suggest some “balance” between good & bad.

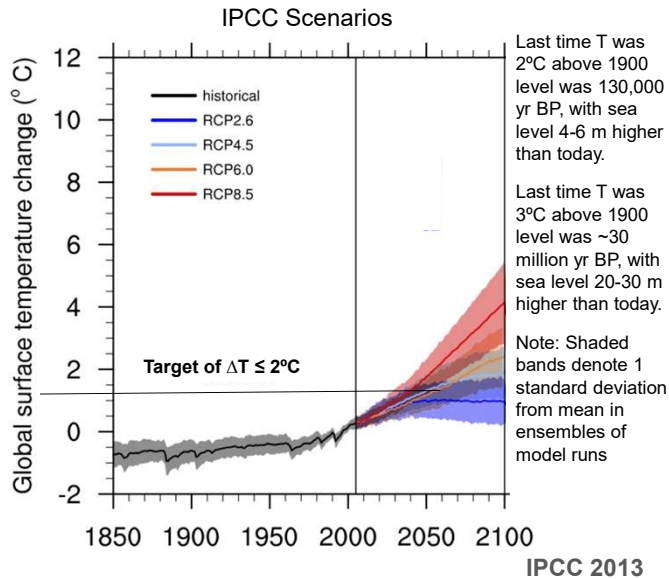
Rebutting the wafflers

Wafflers also underestimate what's coming

Global average T continues to increase under all plausible scenarios.

Momentum in the climate system means T continues to go up even after atmospheric conditions stabilize.

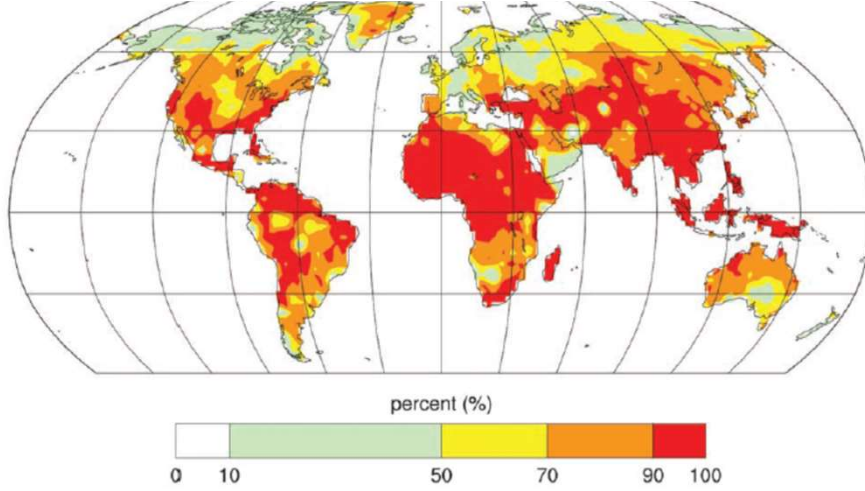
And sea level continues to go up even after T stabilizes.



Rebutting the wafflers

What's coming: Record heat the new normal

Summers in 2080-2100 warmer than warmest on record 1900-2006

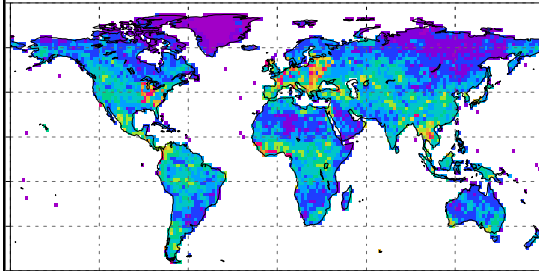


Battisti & Naylor, SCIENCE, 9 January 2009, using IPCC A1B emission scenario

Rebutting the wafflers

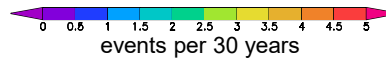
What's coming: Huge increases in drought

Frequency of 4-6 month duration droughts (events per 30 years)



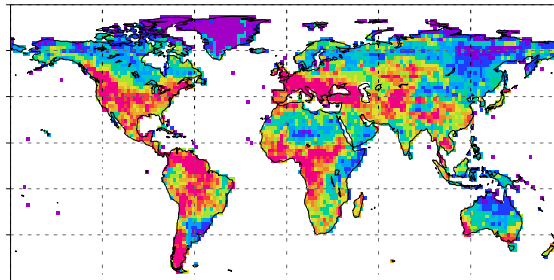
1961-1990

Drought defined as soil moisture below historical 10th percentile value for that calendar month.



Results shown are the mean of 8 global climate models.

Source: Sheffield and Wood 2008 Climate Dynamics (2008) 31:79-105
DOI 10.1007/s00382-007-0340-z

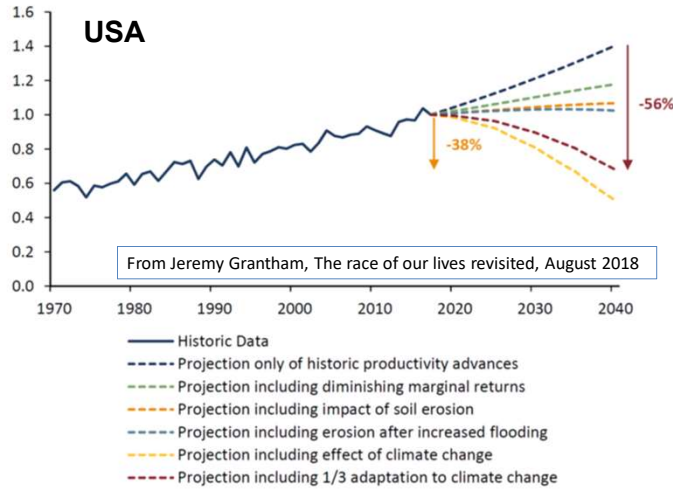


2070-2099, IPCC A2 scenario

Rebutting the wafflers

What's coming: Likely drop in agriculture yields

Index averaging corn, wheat, soy, and rice yields, 2017 = 1



From Jeremy Grantham, The race of our lives revisited, August 2018

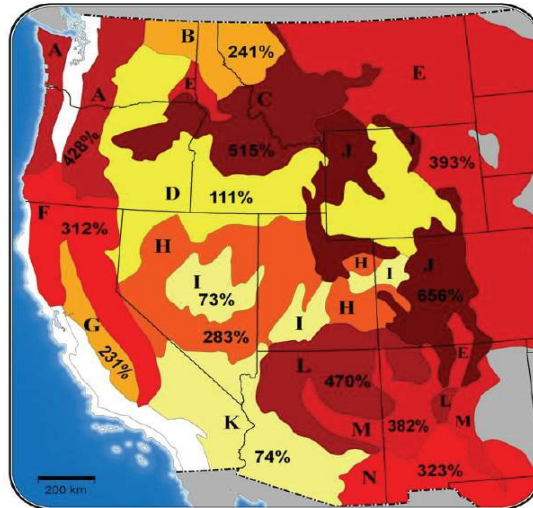
As of 4/30/18
Source: USDA NASS, Rhodes 2014, Liang et al 2017, GMO

Most other countries will do worse.

Rebutting the wafflers

What's coming: Huge worsening of wildfires

Percentages shown are increases in median annual area burned, referenced to 1950-2003 averages, for a 1°C rise in global average temperature.



National Academies, Stabilization Targets, 2010

- A - Cascade Mixed Forest
- B - Northern Rocky Mt. Forest
- C - Middle Rocky Mt. Steppes-Forest
- D - Intermountain Semi-Desert
- E - Great Plains-Palouse Dry Steppe
- F - Sierran Steppe-Mixed Forest
- G - California Dry Steppe
- H - Intermountain Semi-Desert / Desert
- I - Nev.-Utah Mountains-Semi-Desert
- J - South Rocky Mt. Steppes-Forest
- K - American Semi-Desert and Desert
- L - Colorado Plateau Semi-Desert
- M - Ariz.-New Mex. Mts. Semi-Desert
- N - Chihuahuan Semi-Desert

Rebutting the wafflers

What's coming: Increased storminess

PNAS | October 8, 2013 | vol. 110 | no. 41 | 16361–16366

Robust increases in severe thunderstorm environments in response to greenhouse forcing

Noah S. Diffenbaugh^{a,1}, Martin Scherer^a, and Robert J. Trapp^b

SCIENCE 14 NOVEMBER 2014 • VOL. 346 ISSUE 6211 851

Projected increase in lightning strikes in the United States due to global warming

David M. Roms^{1,a}, Jacob T. Seeley¹, David Vollaro², John Molinari²

12610–12615 | PNAS | October 13, 2015 | vol. 112 | no. 41

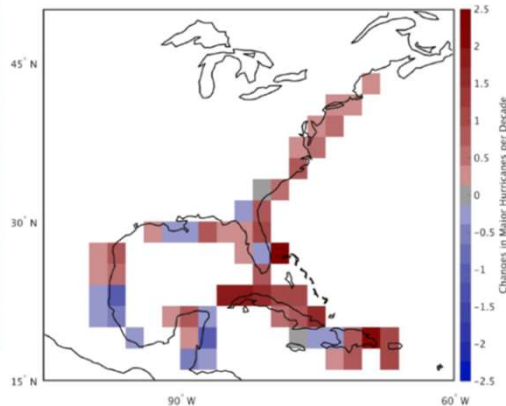
Increased threat of tropical cyclones and coastal flooding to New York City during the anthropogenic era

Andra J. Reed^{a,1}, Michael E. Mann^{a,b}, Kerry A. Emanuel^f, Ning Lin^d, Benjamin P. Horton^{a,f}, Andrew C. Kemp^g, and Jeffrey P. Donnelly^h

Rebutting the wafflers

What's coming: Princeton model projects increase in land-falling Cat 3-5 hurricanes in the Northeast

- By the end of the 21st century, HIFLOR projects more frequent TC landfalls for the United States, especially major hurricane landfalls.
- The largest climate change signal is observed along the east coast, with new threats to northern and inland locations.
- The increased frequency of rapidly intensifying storms, coupled with an increase in the number of landfalling storms, will necessitate new mitigation and forecast strategies to overcome more intense hurricanes impacting coastal cities with little lead time (Emanuel 2017).



These findings are for the IPCC's RCP4.5 emissions scenario—a mid-range case, not the worst!

Figure 6. The difference in landfalling major hurricanes per decade between the HIFLOR 2081-2100 experiment and 1986-2005 experiment. Landfall positions are binned in 2° x 2° grid boxes.

Bhatia and Vechhi, Princeton U, 5 April 2017

Rebutting the wafflers

What's coming: Increased impacts on health

Table 1.3 Additional deaths attributable to climate change,^a under A1b emissions and the base case socioeconomic scenarios, in 2050 **WHO 2017**

Region	Undernutrition ^b	Malaria	Dengue	Diarrhoeal disease ^c	Heat ^d
Asia Pacific, high income		0 (0 to 0)	0 (0 to 0)	1 (0 to 1)	2504 (1868 to 3046)
Asia, central	314 (66 to 563)	0 (0 to 0)	0 (0 to 0)	26 (12 to 38)	1889 (1077 to 2173)
Asia, east	700 (-427 to 1828)	0 (0 to 0)	31 (25 to 42)	72 (33 to 107)	17 882 (11 562 to 24 576)
Asia, south	16 530 (-1582 to 34 642)	9343 (2998 to 13 488)	209 (140 to 246)	7717 (3522 to 11 421)	24 632 (20 095 to 31 239)
Asia, south-east	3049 (605 to 5494)	287 (265 to 334)	0 (0 to 0)	383 (172 to 575)	7240 (5883 to 10 290)
Sub-Saharan Africa, central	18 273 (-12 372 to 48 918)	0 (0 to 0)	1 (1 to 1)	5473 (2473 to 8174)	1363 (1139 to 1598)
Sub-Saharan Africa, eastern	26 480 (4936 to 48 024)	22 194 (18 747 to 26 002)	5 (4 to 5)	6951 (3138 to 10 392)	4543 (3497 to 5957)
Sub-Saharan Africa, southern	1032 (-516 to 2580)	0 (0 to 0)	0 (0 to 0)	267 (121 to 396)	706 (553 to 857)
Sub-Saharan Africa, western	16 105 (-19 500 to 51 709)	524 (524 to 524)	1 (1 to 1)	11 174 (5039 to 16 723)	3469 (2887 to 4261)
World	84 697 (-29 203 to 163 989)	32 695 (22 786 to 40 817)	282 (195 to 342)	32 955 (14 914 to 49 151)	94 621 (70 775 to 126 684)

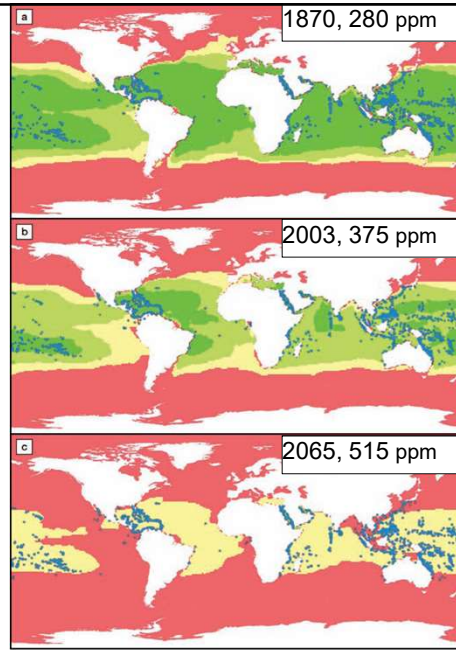
Rebutting the wafflers

What's coming: Ocean acidification gets worse under all scenarios

Adverse effects already being observed.

Adds to warming, pollution, etc. in stressing ocean life

Coral reefs could be dead or in peril over most of their range by mid to late 21st century.

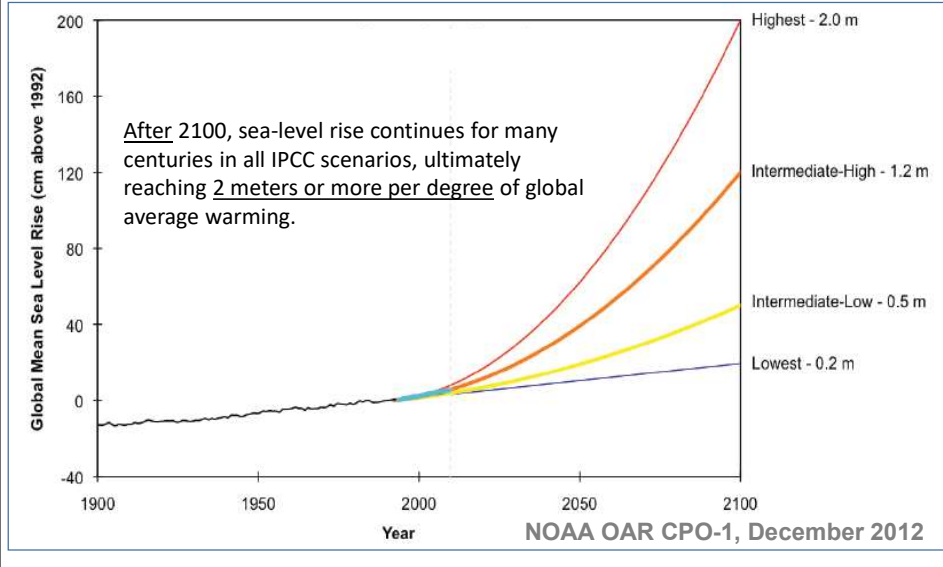


Aragonite saturation Ω
 > 4 Optimal 3.5-4 Adequate 3-3.5 Marginal < 3 Extremely low
 ● Present sites of reef-building warm-water corals

Steffen et al., 2004

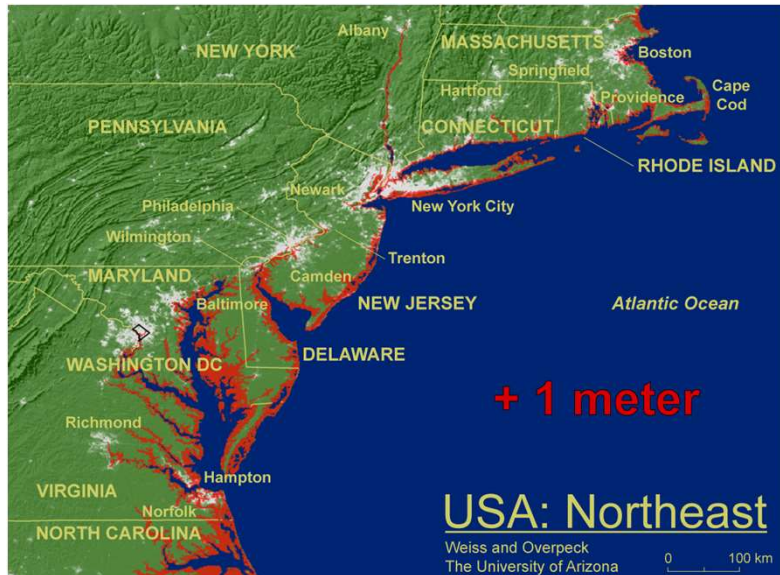
Rebutting the wafflers

What's coming: Sea-level rise continues in all scenarios and accelerates in most



Rebutting the wafflers

Area flooded at high tide with 1 meter SLR



I think this outcome is all too plausible by 2050.

Rebutting the wafflers

The wafflers also minimize what might happen

- Sea-level could rise as much 3-5 m this century from disintegration of Greenland and Antarctic ice sheets.
- Rapid CH₄ and CO₂ release from thawing permafrost & warming Arctic sediments could accelerate all climate-related impacts
- Massive drying & fires could afflict the (formerly) moist tropics, with huge damage to local peoples & biodiversity
- Ocean fisheries could crash from combination of warming, acidification, oxygen depletion, toxics, overfishing...
- Atlantic ocean overturning circulation could collapse, shutting down the Gulf Stream

All of these become more likely as ΔT rises above 1.5°C.

Rebutting the wafflers

The wafflers views on what to do

The wafflers mostly want to postpone aggressive action to reduce emissions. As alternatives, they propose....

- research & development (R&D) on better technologies so emissions reductions can be made more cheaply in the future
- accelerating economic progress in the developing countries as the best way to reduce their vulnerability to climate change
- counting on adaptation as needed, going forward, to limit the damage from whatever changes in climate materialize

(Of course, the wafflers in the top positions in the Trump administration are, with surpassing cynicism, cutting support, or proposing to cut it, for all of these approaches.)

Rebutting the wafflers

The wafflers views on what to do (continued)

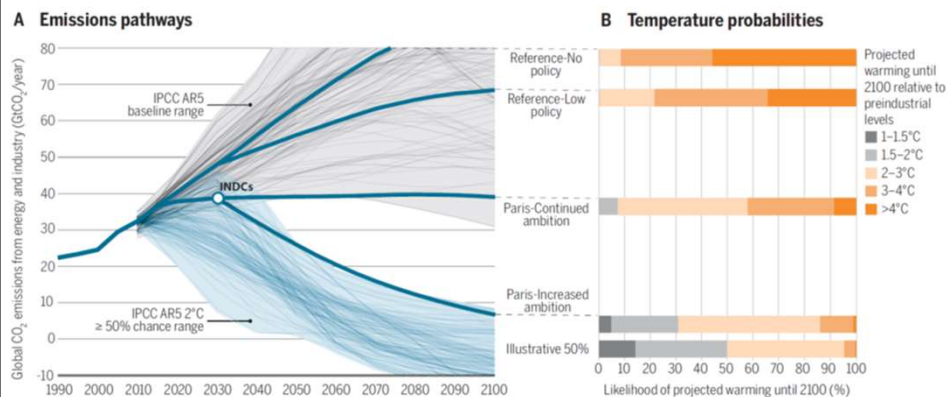
Even if implemented, the wafflers' favored approaches would be grossly inadequate.

- Clean-energy R&D is essential to provide options for the next stage of deep emissions reductions, but we need to start reducing now with the technologies we already have.
- Economic development and climate-change mitigation & adaptation are not “either-or” but must be pursued together. New infrastructure and energy for development need to be climate-friendly & resilient.
- Adaptation gets more difficult, more expensive, and less effective the larger are the changes in climate to which society must adapt.

Rebutting the Wafflers

Deep emission reductions must start now

Emissions pathways & ΔT probabilities



Fawcett et al., SCIENCE, December 4, 2015

“Low Policy” case gives ~35% chance of $\Delta T > 4^\circ\text{C}$ by 2100.

“Paris Increased Ambition” case gives only ~30% chance of $\Delta T < 2^\circ\text{C}$ by 2100.

Rejecting Surrender

“Between fatalism and complacency lies urgency.”

*Jake Sullivan, National Security Advisor
to Vice President Biden*

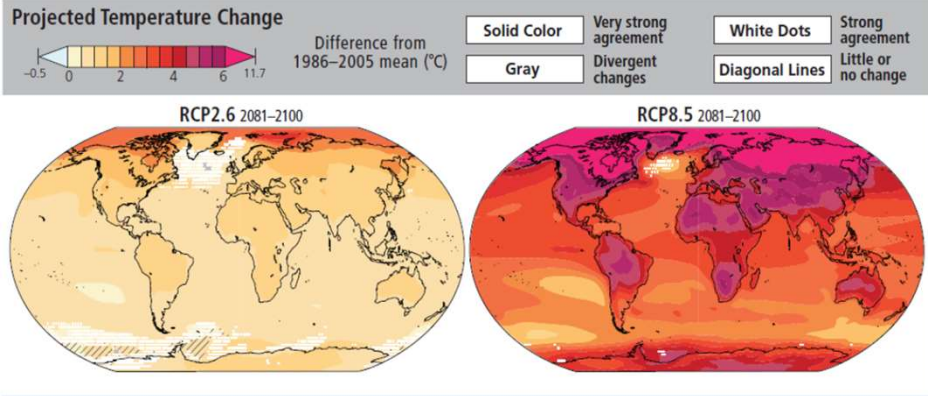
Rejecting Surrender

About society's options

- The options are mitigation, adaptation, & suffering.
- Society is already doing some of each.
- What's up to us is the future mix.
- Minimizing the amount of suffering in that mix can only be achieved by doing a lot of mitigation and a lot of adaptation. Because...
 - Mitigation alone won't work because climate change is already occurring & can't be stopped quickly.
 - And adaptation alone won't work because adaptation gets costlier & less effective as climate change grows.
- We need enough mitigation to avoid the unmanageable, enough adaptation to manage the unavoidable.

Rejecting Surrender

Low future emissions produce far less climate change than high future emissions.



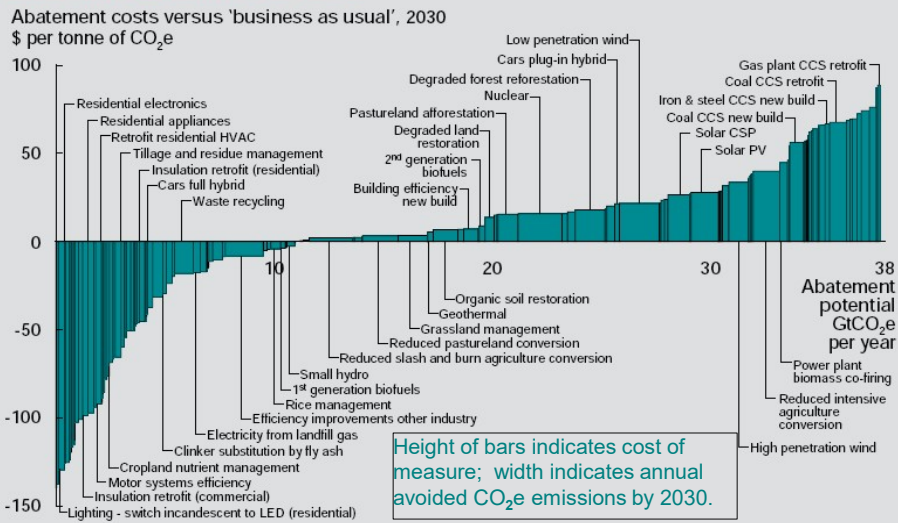
IPCC WGII, 2014

Most uncertainty about the future extent of climate change resides in society's choices, not in the science.

Rejecting Surrender

Is aggressive mitigation affordable?

Mitigation supply curve for 2030: aiming for 450 ppm CO₂e



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below \$90 per tCO₂e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
 Source: McKinsey Global GHG Abatement Cost Curve v2.0

Rejecting Surrender**Is this much mitigation affordable?**

- Thought experiment: Say McKinsey analysis is about right. Then being on 2°C curve in 2030 would require a carbon price of \$70 per ton of CO₂e (in 2015 dollars).
 - The total tax bill of ~\$2 trillion/yr isn't society's cost, because the average cost of reduction would be << \$70 per ton. Gov'ts could rebate the tax receipts on a per capita basis.
 - GWP in 2030 at 2.5%/yr growth between now and then would be \$170 trillion, so even \$2 trillion would be only ~1%.
- World now spends ~2% of GWP on defense; USA spends 3.5% of GDP on defense, 1.7% on environmental protection.
- Such costs are not dead losses, just a choice of how society allocates its resources.
- Most economic models find aggressive mitigation reduces GWP by 2-3% in 2100, but they underestimate innovation and, probably, co-benefits.

Rejecting Surrender**Economics of climate action** (continued)

- Many adaptation measures would make economic sense even if climate were not changing:
 - There have always been heat waves, floods, droughts, wildfires, powerful storms, crop pests, and outbreaks of vector-borne disease, and society has always suffered from being underprepared.
 - It's particularly perverse that the Trump administration has been reversing even the "win-win" adaptation-preparedness-resilience measures adopted under Obama.
- Most reputable studies suggest that the economic damages from not adequately addressing climate change would far exceed the costs of adequately addressing it.
- This and the economic opportunities in clean & resilient technologies are why many states, cities, and businesses support aggressive climate action.

Rejecting Surrender

The idea that society cannot afford to address climate change is wildly wrong.

We cannot afford not to.