Why the Wafflers are Wrong: Addressing Climate Change is Urgent (and a Bargain)

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Outline of these remarks

- Fundamentals of global climate change (CC)
- Categorizing contrarian confusions
  - Denial
  - Waffling
  - Surrender
- Rebutting denial: How we know CC is real
- Rebutting waffling: How we know CC urgent
- Rejecting surrender: How we know fixing CC will be a bargain
“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.
Civilization’s CO$_2$ emissions tracked the rise of fossil-fuel use & deforestation

Roughly, coal is CH, oil is CH$_2$, natural gas is CH$_4$, and wood is CH$_2$O. In each case, their combustion produces CO$_2$ and H$_2$O, all going into the atmosphere.

The H$_2$O stays in the atmosphere only briefly, so the additions do not accumulate there. But some of the CO$_2$ 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 one from the Industrial Revolution.

The 2016 CO₂ concentration was 403 ppmv, 45% higher than 1750.

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

Updated from IPCC AR4, WG1 SPM, 2007
Humans have added other heat-trapping gases too

Most important are methane (CH$_4$) & nitrous oxide (N$_2$O) from energy systems & agriculture and CFCs and (most recently) CFCs & HFCs from consumer products & industry

The forcing from the non-CO2 gases is smaller than that from CO2, but not insignificant.

USGCRP 2017
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.
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”.
The T change is highly non-uniform

Uneven T change → changes in atmospheric & ocean circulation.
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

When the average of any of these weather variables changes, the extremes change much more.

The principle holds for any “normally distributed” climate variable: A modest change in the average $\rightarrow$ big changes at the “tails”.

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 Confusions

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

Mark Twain
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.”
Classes of contrarian arguments

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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
There is no scientific doubt the world is warming. Trends in every relevant indicator are consistent.
Rebutting the deniers

**There was no “hiatus”**

“Hiatus means “pause”. The claim that there was a pause in warming for 10-15 years after 1998 rests on the fact that the anomalously high 1998 T (boosted by a strong El Niño) was not exceeded until 2005 and was about the same as the 2009 and 2013 values.

This claim “cherry picks” specific dates to compare, in contrast to the scientific procedure of finding the best-fit straight line through all the years in the period of interest. By that standard, warming was slower between 1998 and 2013 than in the preceding 15 years, but it didn’t pause (red line is best fit).
Rebutting the deniers

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

Blue band is one-sigma uncertainty range (68% confidence interval).

Natural influences—mainly variations in Earth’s orbit and axis of rotation—were in a long-term cooling phase that would have continued for 1000s of years more but for the influence of humans.
Rebutting the Wafflers

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

Donella Meadows, co-author of Limits to Growth (1971)
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.
Climate change is already causing serious harm
Around the world we’re seeing, variously, increases in
• floods
• drought
• wildfires
• heat waves
• coral bleaching
• ocean acidification
• coastal erosion & inundation
• power of the strongest storms
• permafrost thawing & subsidence
• expanding impacts of pests & pathogens
• altered distribution/abundance of valued species

All are plausibly linked to climate change by theory, models, and observed “fingerprints”; most growing faster than projected.
A warmer atmosphere holds more water, so more can (and does) come down at one time.
“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.
Downpours ➔ Floods (continued)

Central Europe, May-June 2013

After the floods

Heavy rainfall in central Europe caused record floods. There was also flooding in many other regions of the world. PAGE 16

Munich Re (2014)
Growing harm: In a wetter world overall, many drought-prone regions are getting more so!

California’s Folsom Lake at 17% capacity, 02-02-14

Credit: Ken James / Bloomberg
Growing harm: drought (continued)

- 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 can also play a role.

![U.S. Drought Monitor Map](image)
Growing harm: Drought in the Amazon

Precipitation index for Brazil, 1/15 – 12/16
Growing harm: Floods and droughts in China

30-year weakening of East-Asia monsoon – attributed to global climate change -- has meant less moisture flow South to North over China, producing increased flooding in South, drought in North, with serious impacts on agriculture.

Qi Ye, Tsinghua University, May 2006
Growing harm: Wildfires

Millions of acres burned annually in U.S. wildfires
1981 - 2015

Contributing factors are heat, drought, more dead trees killed by pests, and more lightning in a warming world.
Wildfires

- 3.4 million acres had already burned in the USA in 2017 by the beginning of July.
- The fire season in the USA is about 3 months longer than it was 40 years ago.
- The average fire is much bigger & hotter than before. Small wildfires burn at 1300-1400°F; big ones can burn at 2000°F or more, spreading faster, with far greater risks for firefighters.
- In Alaska, even the tundra has experienced wildfires in recent years.

The Biggest Western Fires Burning Right Now

At last count, more than 60 wildfires were burning across the U.S. West. These were the largest fires on July 11, 2017.

SOURCE: U.S. Forest Service
Rebutting the wafflers

Growing harm: huge increase in heat waves


Portion of Northern Hemisphere land experiencing > 3σ summer heat in a given year increased from 0.1-0.2% in 1951-80 to 10% in 2001-2011—a 50- to 100-fold increase.
Rebutting the wafflers

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

Wet Bulb Global Temperatures (WGBT) are 1980-2009 averages for hottest month.

IPCC AR5, WGII, Figure 11-5
Growing harm: Coral bleaching

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

Growing harm: Ocean acidification

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

The link is that dissolved CO₂ forms weak carbonic acid (\( \text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{H}_2\text{CO}_3 \)), lowering the pH.
Growing harm: Death of coral reefs in Florida Keys

Florida’s coral reefs are being devastated by multiple stresses, of which warming water and acidification are the most important.

Less than 10% of the reef system is now covered by living coral. (Red circles show percentage declines since 1996.)

NASA Aqua satellite imagery. Washington Post, 26 June 2017
Rebutting the wafflers

Growing harm: thawing/subsiding permafrost

Norwegian Polar Institute, 2009

Russia

Fairbanks, AK

Norwegian Polar Institute, 2009
Rebutting the wafflers

Growing harm: Accelerating sea-level rise

Loss of land ice, thermal expansion, pumping pumping of groundwater all contribute.

WMO 2017
Rebutting the wafflers

Growing harm: rising sea $\rightarrow$ coastal inundation

Rebutting the wafflers

Growing harm: Rising sea → Coastal erosion

Cape Cod Times
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
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 \( \rightarrow \) 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.
Growing harm: Pest outbreaks

Pine bark beetles, with a longer breeding season courtesy of warming, devastate trees weakened by heat & drought in California, Colorado, Alaska…
Growing harm: Disease vectors & pathogens

How climate change affects your health

Vector-borne diseases

- Increased flooding & storms
- Increased duration of warm season
- Changes in median temperature
- Expanded geographical range
- Changes in vector behaviors


42,000 cases of West Nile Virus in the U.S. since 1999, of which more than 1,700 people have died.

About 68% of California will have increased probability for West Nile virus by 2050.

As temperature rises, the range of ticks carrying Lyme disease will expand.

1 The Climate Nexus: http://climate.nex.us
2 Climate Nexus: http://climate.nex.us
3 Panos/Climate Nexus: http://climate.nex.us
4 http://PanosClimateNexus.com/ClimateNexus/ClimateNexus/ClimateNexus/ClimateNexus/
Rebutting the wafflers

Growing harm: Impacts on valued species

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

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

Valued species: Walruses impacted by shrinking sea ice

Along with whales, seals, polar bears

Courtesy Fran Ulmer
In the face of these observed & growing impacts, the arguments of some wafflers that climate change is “good for us” seem perverse

• Some places may benefit from longer growing seasons, warmer winters, & increased CO\textsubscript{2} 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.
  – CO\textsubscript{2} 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.

Last time T was 2ºC above 1900 level was 130,000 yr BP, with sea level 4-6 m higher than today.

Last time T was 3ºC above 1900 level was ~30 million yr BP, with sea level 20-30 m higher than today.

Note: Shaded bands denote 1 standard deviation from mean in ensembles of model runs.
What’s coming: Increases in heat extremes

Dramatically increasing chance of extremely hot summers since the 2003 European heatwave

Nikolaos Christidis*, Gareth S. Jones and Peter A. Stott

Rapid increase in the risk of extreme summer heat in Eastern China

Ying Sun¹, Xuebin Zhang²*, Francis W. Zwiers³, Lianchun Song¹, Hui Wan², Ting Hu¹, Hong Yin¹ and Guoyu Ren¹

Future population exposure to US heat extremes

Bryan Jones¹*, Brian C. O’Neill², Larry McDaniel³, Seth McGinnis³, Linda O. Mearns³ and Claudia Tebaldi²
Rebutting the wafflers

Summer heat in SW Europe—history & BAU future

The 2003 heatwave killed 35,000-70,000 people in France, Spain, & Italy.

Summers as hot as 2003 will likely be the norm by the 2040s and will be considered unusually cool by the 2060s.
Rebutting the wafflers

US heatwaves at mid-century under BAU

http://www.climate.gov/sites/default/files/Heatwave_days2040-2070_HR.jpg
Rebutting the wafflers

What’s coming: Declining crop yields

These declines are without taking into account any increase in major droughts.

National Academies, Stabilization Targets, 2010

Local Warming (°C) for
Low Latitudes
0 1.2 2.4 3.6 4.8
0 1.5 3.0 4.5 6.0
Mid-High Latitudes

Yield Change (%)

Global Temperature Change (°C)

US Maize
US Soybean
Asia Rice
India Wheat
Africa Maize
Rebutting the wafflers

What’s coming: Huge increases in drought

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

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

Results shown are the mean of 8 global climate models. Cape Cod drought frequency reaches 5x historical value.

Rebutting the wafflers

What’s coming: Worse wildfires

Area burned by wildfires, already up substantially, is projected to go up much more.

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

National Academies, Stabilization Targets, 2010
Rebutting the wafflers

What's coming: Increased storminess

Robust increases in severe thunderstorm environments in response to greenhouse forcing
Noah S. Diffenbaugh, Martin Scherer, and Robert J. Trapp

Projected increase in lightning strikes in the United States due to global warming
David M. Romps, Jacob T. Seeley, David Vollaro, John Molinari

Increased threat of tropical cyclones and coastal flooding to New York City during the anthropogenic era
Andra J. Reed, Michael E. Mann, Kerry A. Emanuel, Ning Lin, Benjamin P. Horton, Andrew C. Kemp, and Jeffrey P. Donnelly
Rebutting the wafflers

Princeton hurricane 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!
Sea-level rise continues for many centuries after 2100 in all scenarios, ultimately reaching 2 meters or more per degree of global avg warming.
Rebutting the wafflers

**Sea level: Flooded area with 1 meter rise**
What’s coming: Continued drop in ocean pH, with big impacts on marine life

Increased acidity lowers the availability of CaCO\textsubscript{3} to organisms that use it for forming their shells & skeletons, including corals.

Adverse effects are already being observed.

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

Steffen et al., 2004
Rebutting the wafflers

**The wafflers also minimize what could happen**

- Greatly accelerated sea-level rise from rapid disintegration of Greenland and Antarctic ice sheets
- Rapid CH$_4$ and CO$_2$ release from thawing permafrost & warming Arctic sediments, accelerating all climate-related impacts
- Massive drying & fires in the (formerly) moist tropics, with huge damage to local peoples & biodiversity
- Ocean fisheries crash caused by combination of warming, acidification, oxygen depletion, toxics, overfishing...
- Collapse of the Atlantic Meridional Overturning Circulation, shutting down the Gulf Stream

*All of these become more likely as ΔT rises above 1.5°C.*
The wafflers views on what to do

The wafflers mostly want to postpone aggressive action to reduce emissions starting now in favor of....

- 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 deniers and the wafflers in the top positions in the Trump administration are, with surpassing cynicism, busy cutting support for all of these approaches.)
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 be reducing now with the technologies we already have.

• Economic development and climate-change mitigation & adaptation are not “either-or” but must be pursued together. Energy for development and new infrastructure 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
Rejecting Surrender

“Climate change is not just a great challenge; it’s a great opportunity”

Countless wise observers
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.

Most uncertainty about the future extent of climate change resides in society’s choices, not in the science.
Is aggressive mitigation affordable?

Mitigation supply curve for 2030: aiming for 450 ppm CO$_2$e

Height of bars indicates cost of measure; width indicates annual avoided CO$_2$e emissions by 2030.

Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below $90 per tCO$_2$e 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
Is this much mitigation affordable?

- Achieving all the reductions on the McKinsey cost curve would require a carbon price of $70 per ton of CO$_2$e by 2030 (in 2015 dollars).
  - The total tax bill of $2 trillion per year is not the cost, because the average cost of reduction would be much less than $70 per ton. Society could spend the difference in other ways.
  - GWP in 2030 at 2.5%/yr growth between now and then would be $170 trillion, so even the $2 trillion figure would be ~1%.
- World now spends 2.5% of GWP on defense; USA spends 5% on defense, 2% on env protection.
- These costs are not a dead loss, just a choice of how society allocates its resources.
- Most economic models find aggressive mitigation reduces GWP by 2-3% of GWP in 2100, but they underestimate innovation.
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-born 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 measures adopted under Obama.

• Virtually all 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 cities and businesses support aggressive climate action.
Rejecting Surrender

7,477 + Cities

Representing

685 Million People

9% of Total Global Population

In other words, the world’s largest coalition of cities fighting climate change.

Global Covenant of Mayors for Climate & Energy

Compact of Mayors

Covenant of Mayors for Climate & Energy
One thousand companies and investors have signed the Business Backs Low-Carbon USA statement since November 2016. Companies and investors wishing to add their name to the statement can do so by registering here. For media inquires, please contact: Peyton Fleming fleming@ceres.org or Melanie Gade melanie.gade@wwfus.org.

Dear President Trump, Members of the US Congress, and Global Leaders:
The idea that society cannot afford to address climate change is wildly wrong.
“Trend is not destiny.”

Rene Dubos

Thank you!