Climate Change & Critical Thinking

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Feel free to ask questions whenever…

Topics

- Definitions: Climate Change and Critical Thinking
- Overview of Critical Thinking
- Overview of Weather & Climate
- Overview of Climate Change
- How do Climate Change and Critical Thinking relate to each other?
- Audience take-aways

Definitions

Climate Change

- Climate = the weather conditions in an area averaged over some time frame
- Climate Change = a change in global or regional climate patterns

Critical Thinking

- Critical = involving an analysis of the merits and faults of a work

  e.g. movie 'critic'
- Critical thinking = **objective** analysis and evaluation of an issue to form a *judgment*

Let's consider critical thinking first…

Critical Thinking Overview

Facts exist!

Reality is real!

How does one analyze/evaluate something to form a judgement?

One possibility: The Scientific Method
Ask a question, do background research, construct hypothesis, test with experiment, analyze data and draw conclusions. Do results support hypothesis? Communicate results.

The most important element in critical thinking:

Consider the source of information! *Background research?*

teachers
professors
scientists
doctors
co-workers

your BFF
your parent
your significant other
friends
family

politicians
newspapers
network news
cable news
Facebook/Twitter

Considering the source:

- *What is their motivation? Why are they interacting with you? To educate you? To help you? To get your vote? To make money?*
- *What is their history? Have they been truthful, helpful in the past? Are their words and actions consistent with each other? Consistent with what they've said and done in past? Consistent with those of other people?*
- *What are their expertise, knowledge, skills, education?*
- *Have their statements/comments/communications undergone any kind of quality control?*

Challenges/Impediments to Critical Thinking

- Emotion --everyone has emotions, need to take them into consideration

frontiers in PSYCHOLOGY

ORIGINAL RESEARCH ARTICLE
published: 10 June 2014
doi: 10.3389/fpsyg.2014.00570

How emotions affect logical reasoning: evidence from experiments with mood-manipulated participants, spider phobics, and people with exam anxiety

Nadine Jung†, Christina Wranke†, Kai Hamburger* and Markus Knauff

Experimental Psychology and Cognitive Science, Justus Liebig University, Giessen, Germany

- Recent experimental studies show that emotions can have a significant effect on the way we think, decide, and solve problems.
- Results showed a clear effect of emotions on reasoning performance.
- Participants in negative mood performed worse than participants in positive mood, but both groups were outperformed by the neutral mood reasoners.

Challenges/Impediments to Critical Thinking

What is your Worldview?

- Protecting Worldview/Confirmation bias – tendency to search for, interpret, favor and recall (sometimes ambiguous) information in a way that confirms one's pre-exisiting beliefs or hypotheses

Be careful of Imposter Syndrome

- Explicit bias – attitudes & beliefs about yourself, a person or group on a conscious level. Should be controllable.

For both of these, knowing about them helps you deal with them. Knowledge is power…

16Personalities

EDUCATION PLANNER.org

Find out more about yourself.

Use these interactive self-assessments to discover what you're good at and where you may have room for improvement. Identify the things that interest you and get some ideas about careers to explore.

http://www.educationplanner.org/students/self-assessments/learning-styles.shtml
https://www.16personalities.com

Challenges/Impediments to Critical Thinking

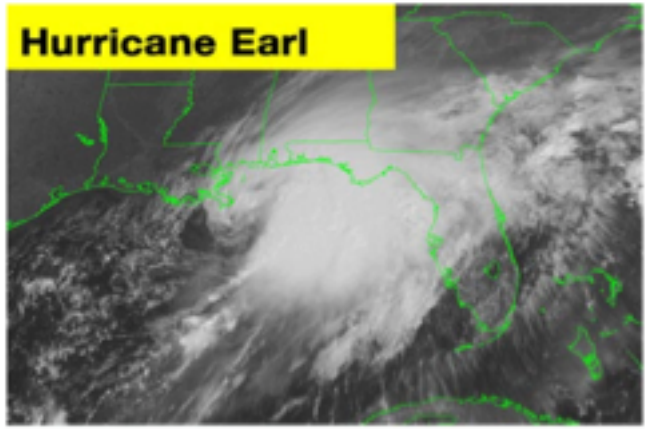
- Implicit bias – attitudes & beliefs we have about persons or groups on a ***subconscious*** level
  - Pervasive: Everyone has implicit bias
  - Implicit biases can be difficult to identify
  - Implicit bias may *not* align with our declared beliefs
  - Our implicit biases tend to favor our own ingroup
  - Implicit biases predict our behavior

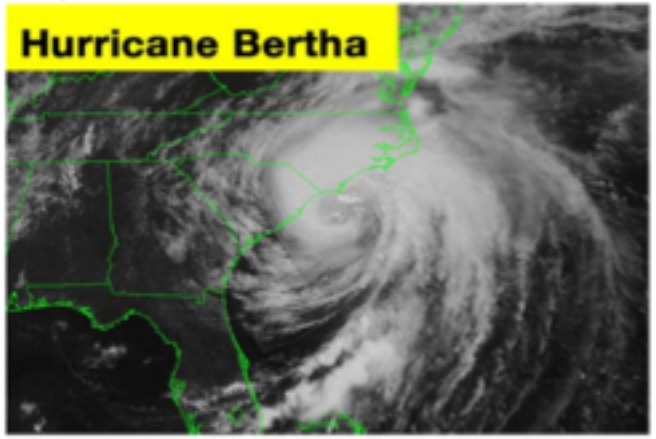
THE OHIO STATE UNIVERSITY
KIRWAN INSTITUTE FOR THE STUDY OF RACE AND ETHNICITY

kirwaninstitute.osu.edu

  - Lookdifferent.org

Which hurricane is more dangerous?





Female hurricanes are deadlier than male hurricanes

Kiju Jung[a,1], Sharon Shavitt[a,b,1], Madhu Viswanathan[a,c], and Joseph M. Hilbe[d]

PNAS June 17, 2014. 111 (24) 8782-8787; published ahead of print June 2, 2014.
https://doi.org/10.1073/pnas.1402786111

PNAS Proceedings of the National Academy of Sciences of the United States of America

Do people judge hurricane risks in the context of gender-based expectations? We use more than six decades of death rates from US hurricanes to show that feminine-named hurricanes cause significantly more deaths than do masculine-named hurricanes. Laboratory experiments indicate that this is because hurricane names lead to gender-based expectations about severity and this, in turn, guides respondents' preparedness to take protective action. This finding indicates an unfortunate and unintended consequence of the gendered naming of hurricanes, with important implications for policymakers, media practitioners, and the general public concerning hurricane communication and preparedness.

Implicit Bias continued

Project Implicit:
https://implicit.harvard.edu/implicit/

Project Implicit®

We all have implicit bias
Identifying it in ourselves and others facilitates critical thinking

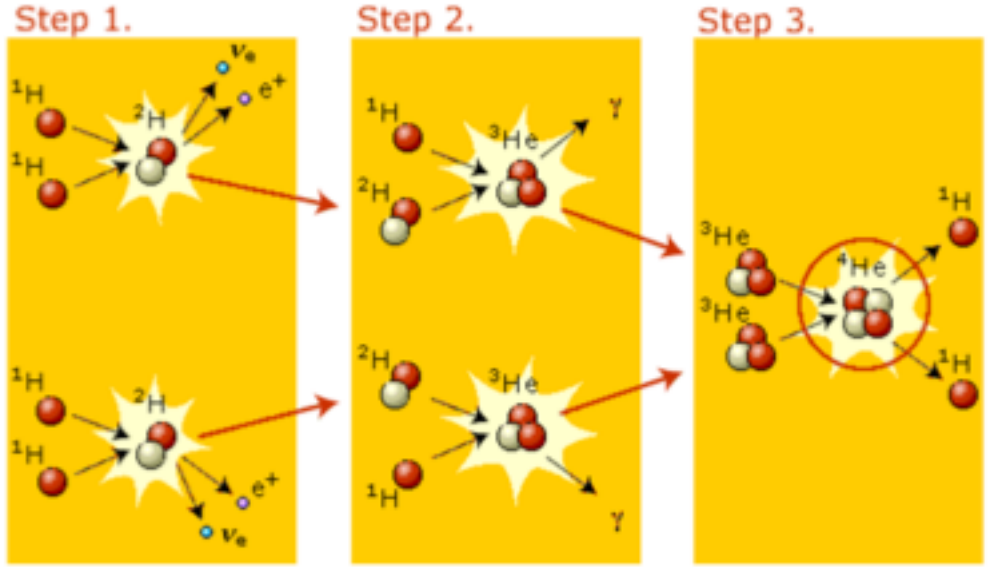
Now …on to climate!

The ultimate source of climate is The Sun

The Sun is a yellow main-sequence star

With potentially~10 billion years of hydrogen fusion

(Sun believed to be ~4.6 billion years old)



Nuclear Fusion

Earth bombarded by energy from Sun.

Fact.

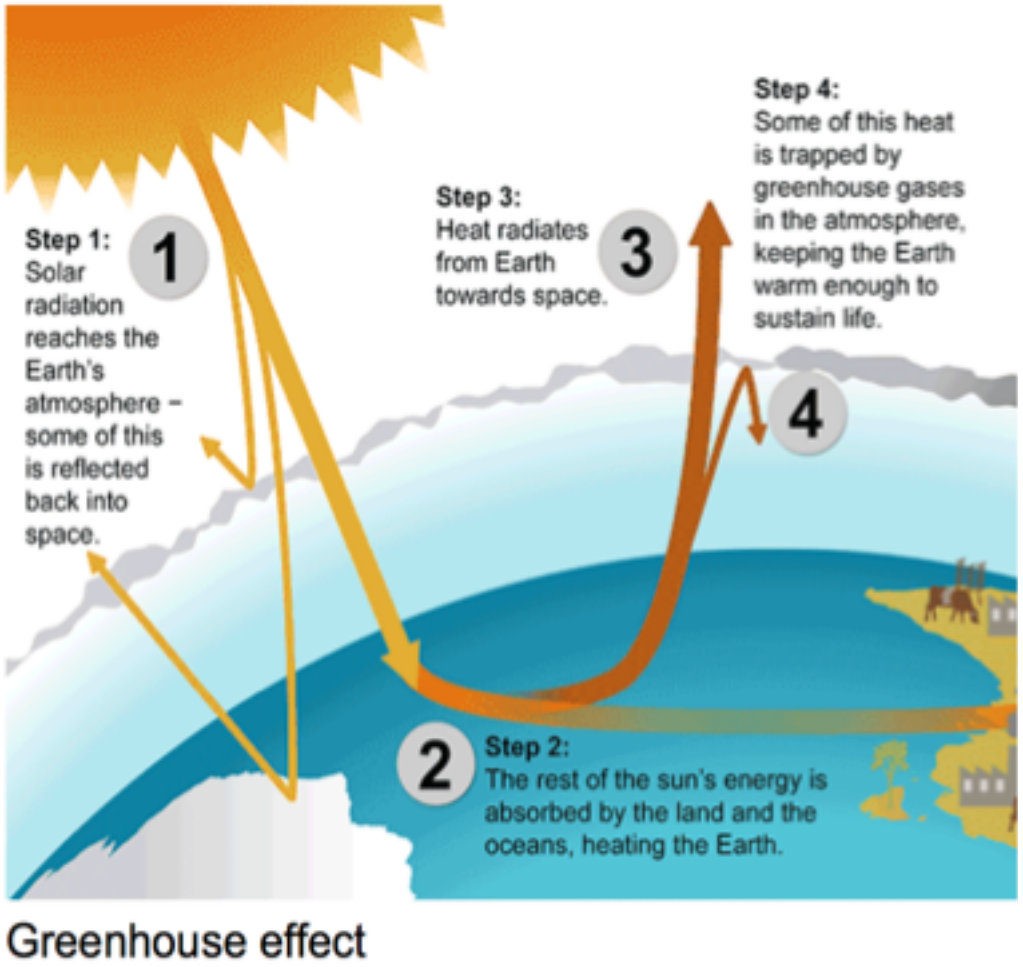
^1H = hydrogen nucleus = proton

^2H = deuterium nucleus = proton+neutron

^3He = helium ion = p + p + n

^4He = helium nucleus = p+p+n+n

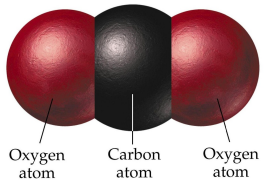
The sun warms the Earth—making life possible…

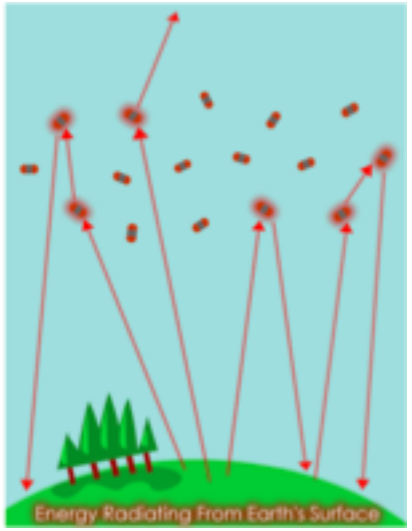


Greenhouse effect

Greenhouse Effect – radiation in atmosphere warms the surface

- Greenhouse gas molecules made of 3 or more atoms
- Their physical makeup means it's easier to absorb energy
- Vibrate when absorb energy
- Eventually release energy – can be absorbed by another greenhouse gas molecule





- Greenhouse Effect is good
- Without it, Earth's global ann temp ~0° (rather than ~57° F)
- Makes Earth habitable

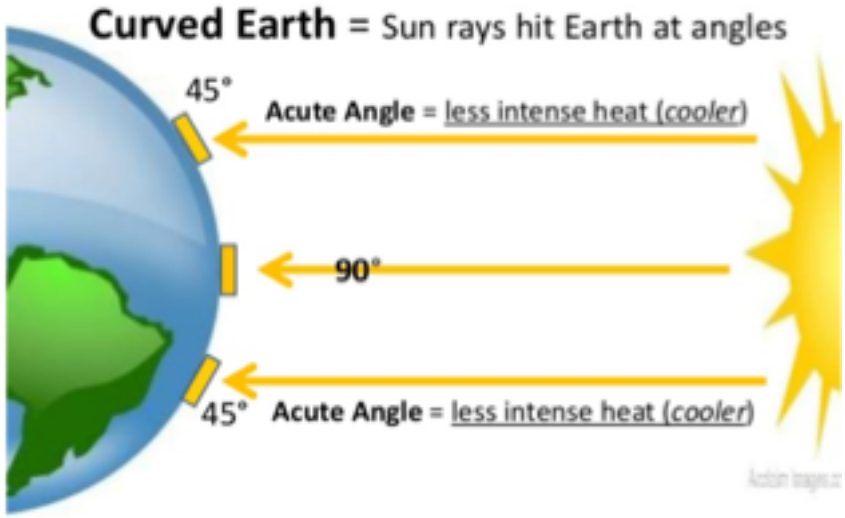
The Greenhouse Effect is a fact.

Why do we have Weather?

Uneven heating of the Earth by the **Sun**.

shape of Earth
day/night
seasons (23.5 ° axis tilt)
annual orbit around sun
land heats up (and cools off) faster than water

Heat/Energy wants to even out.



What is Weather?

Weather = the state of the atmosphere at a particular place and time as regards heat, dryness, sunshine, wind, rain, snow, humidity, etc.

Main weather elements:

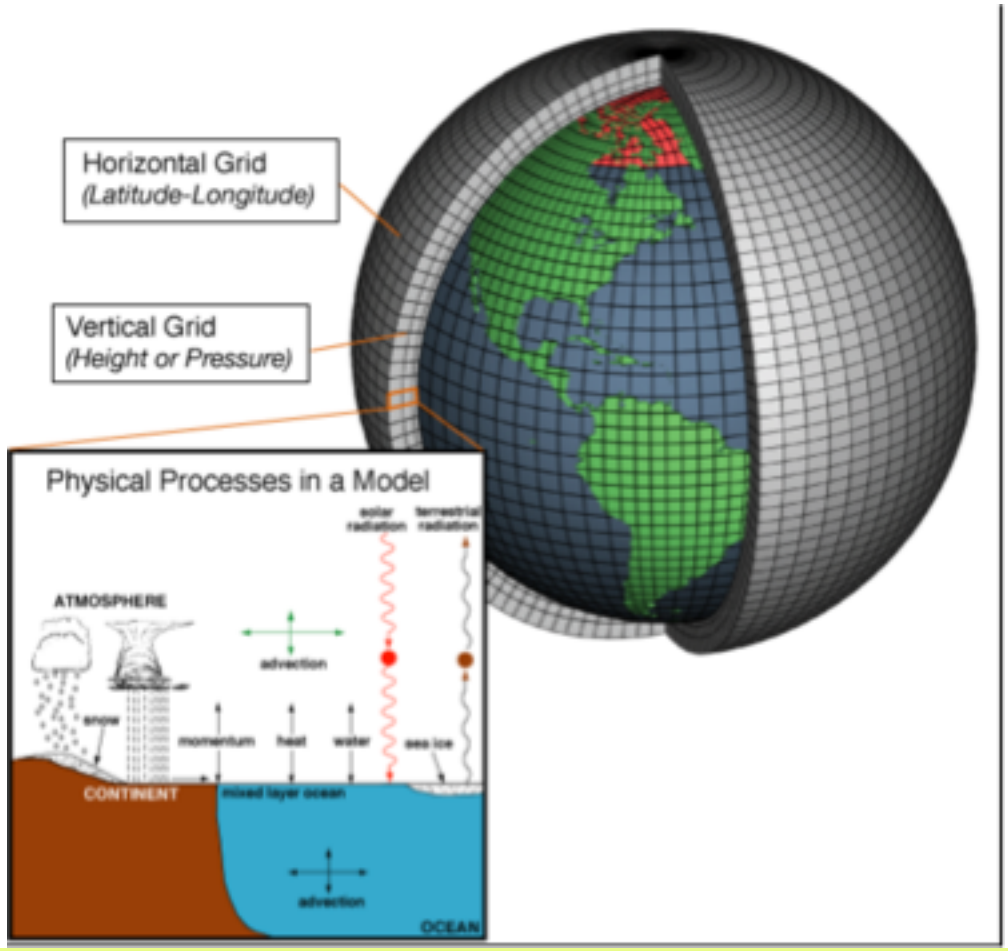
- Wind force
- Wind direction
- Precipitation
- Temperature
- Sunshine
- Visibility
- Clouds

How do we predict weather? Weather Forecasts

Weather Forecasting

Numerical weather prediction uses mathematical computer *models* of the atmosphere and oceans to predict near-future weather based on *current* weather conditions

- Systems of differential equations
- Based on laws of physics, fluid motion, chemistry
- Coordinate system divides planet into 3-d grid
- Winds, heat transfer, solar radiation, relative humidity, surface hydrology calc in each grid cell
- Interactions with neighboring cells are used to calc atmospheric properties in near *future*



NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Weather is what you get; climate is what you expect.

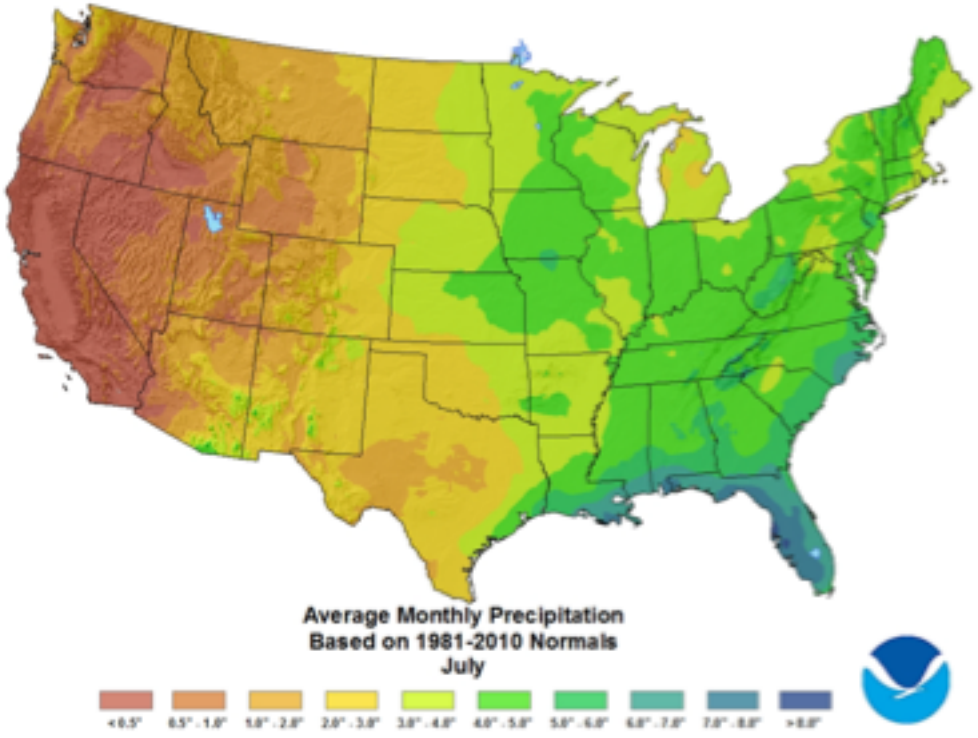
Climate is average weather

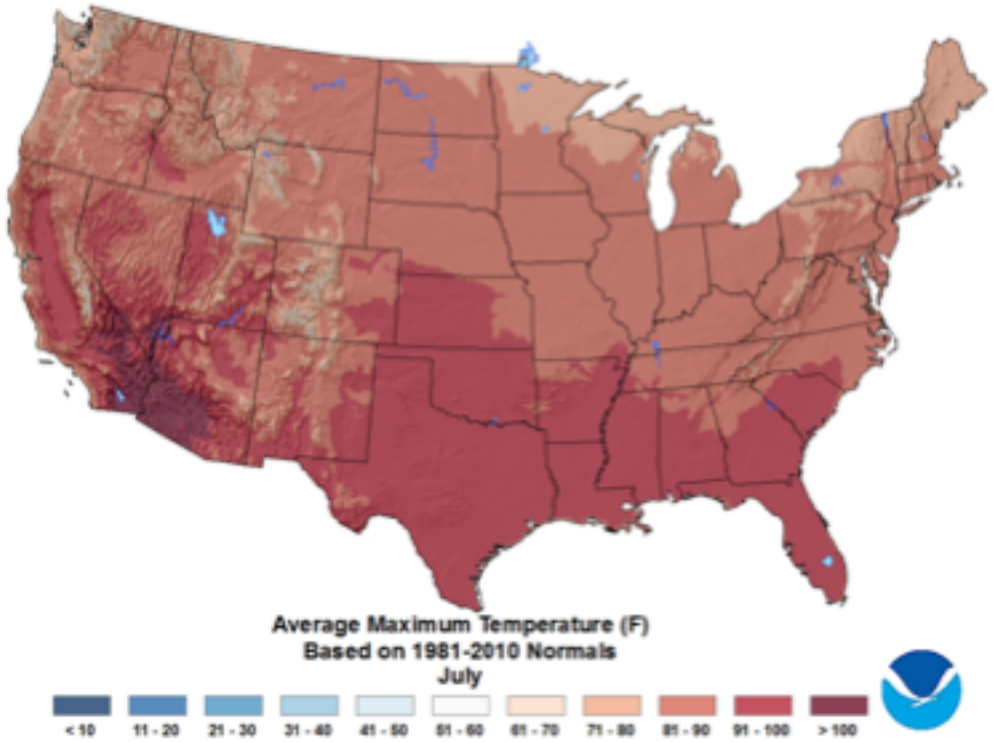
Specify region and time period…

Climate Example

U.S. Climate Atlas

NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION





Climate is *average* weather—time period, region must be specified.

Climate Change?

- Data shows weather changes. Fact.
- Consequently Data shows climate changes. Fact.

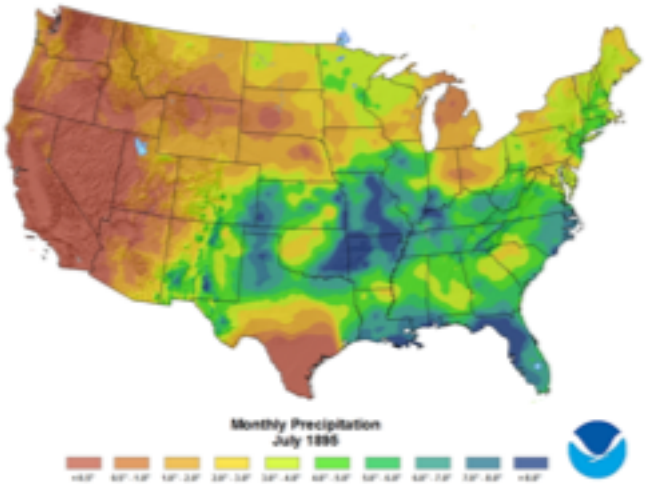
How does climate change?

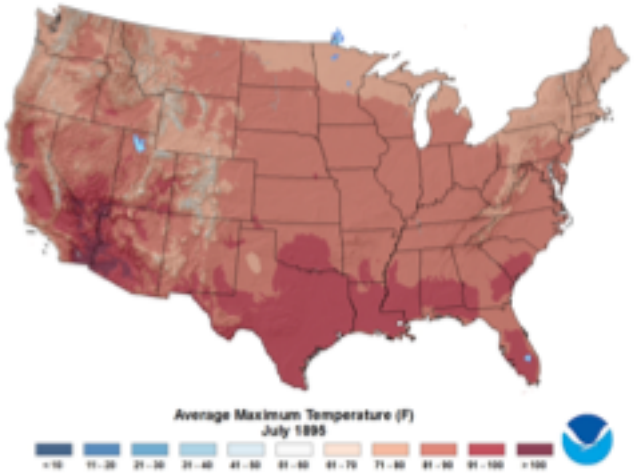
Why does climate change?

What will happen in the future?

A group that has studied this extensively…

looks at *all* the data out there





Intergovernmental Panel on Climate Change (IPCC) http://www.ipcc.ch

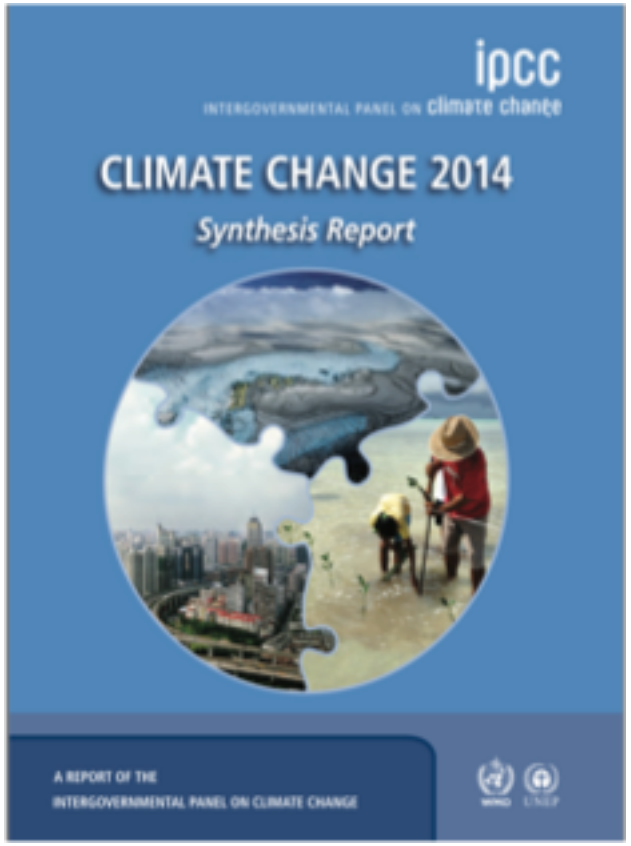
- IPCC: international body for assessing science related to climate change
- Set up in 1988 by the World Meteorological Organization (WMO) & United Nations Environment Programme (UNEP)
- Provide policy makers with regular assessments of
  - Scientific basis of climate change
  - Impacts of climate change
  - Future risks of climate change
  - Options for adaptation to climate change
  - Mitigation of climate change
- 195 member countries
- Assessments written by *hundreds* of leading scientist from around the world
- Assessments reviewed by *thousands* of experts (this is quality control)

Reliable?

IPCC Fifth Assessment Report (AR5)

2014 Synthesis Report
Summary for Policymakers

Anthropogenic=originating in human activity



SPM 1. Observed Changes and their Causes

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. *{1}*

SPM 1.1 Observed changes in the climate system

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. *{1.1}*

Temperature Change

Sea Level Change

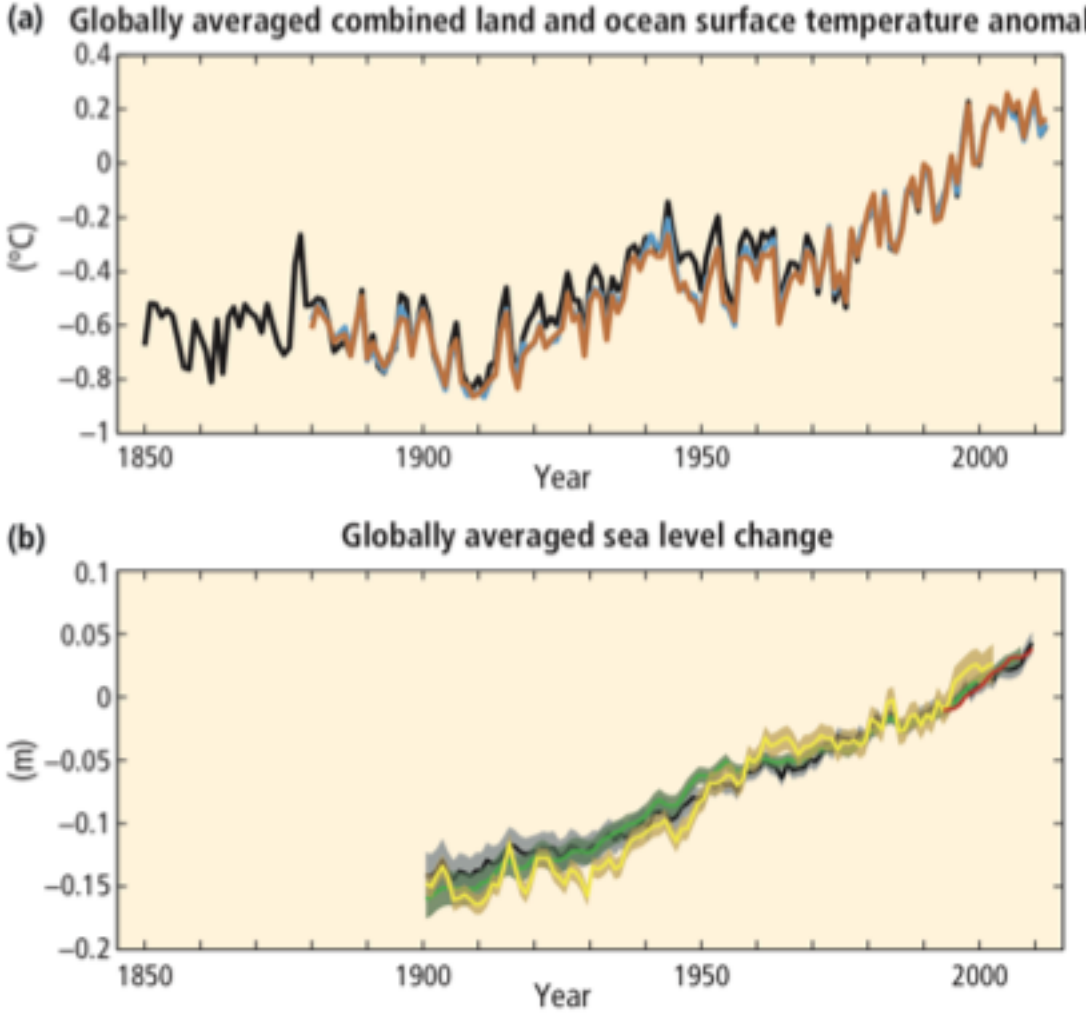
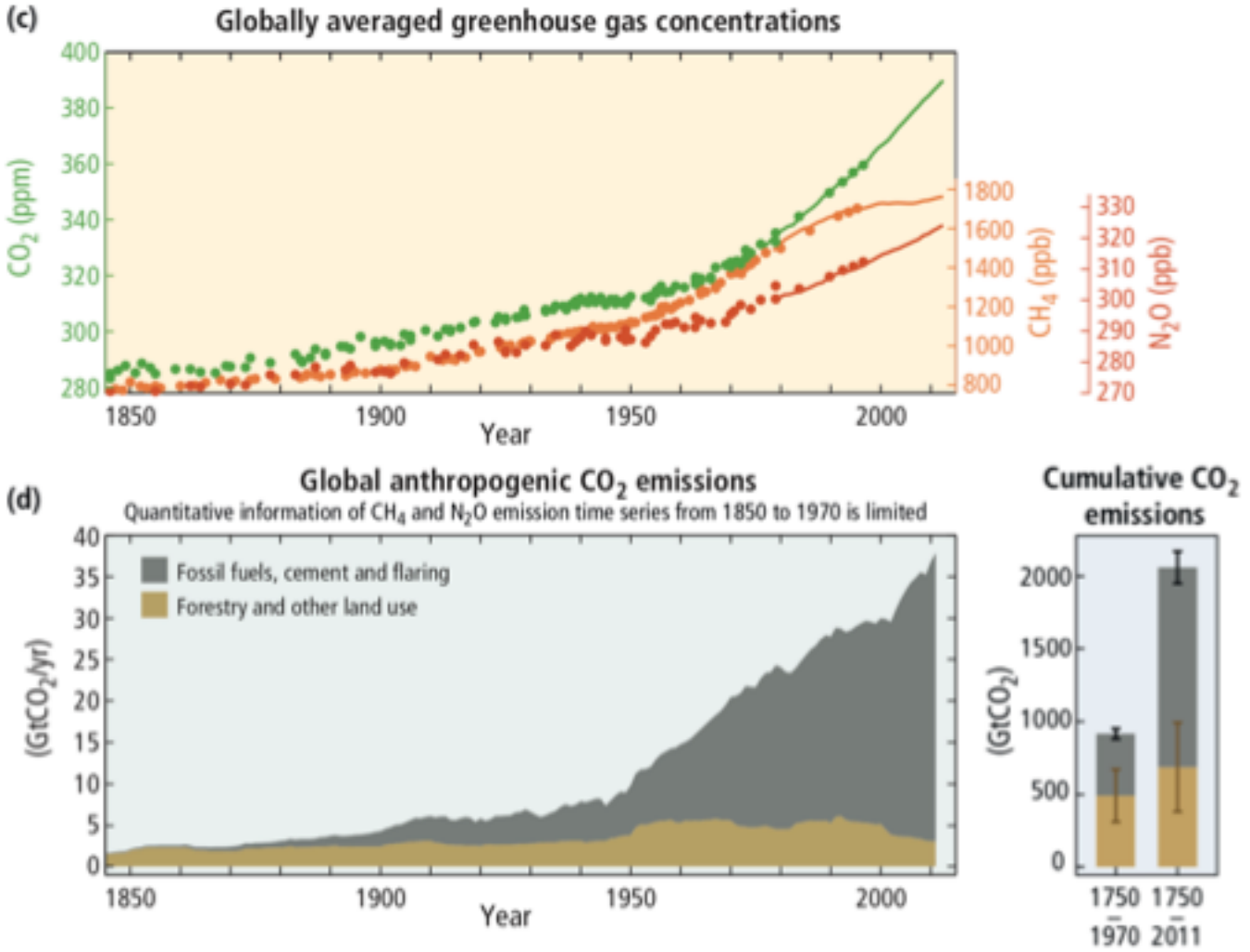


Figure SPM.1 | The complex relationship between the observations (panels a, b, c, yellow background) and the emissions (panel d, light blue background) is addressed in Section 1.2 and Topic 1. Observations and other indicators of a changing global climate system. Observations: **(a)** Annually and globally averaged combined land and ocean surface temperature anomalies relative to the average over the period 1986 to 2005. Colours indicate different data sets. **(b)** Annually and globally averaged sea level change relative to the average over the period 1986 to 2005 in the longest-running dataset. Colours indicate different data sets. All datasets are aligned to have the same value in 1993, the first year of satellite altimetry data (red). Where assessed, uncertainties are indicated by coloured shading. **(c)** Atmospheric concentrations of the greenhouse gases carbon dioxide

Greenhouse Gas Changes

Anthropogenic Emission Changes



data (red). Where assessed, uncertainties are indicated by coloured shading. **(c)** Atmospheric concentrations of the greenhouse gases carbon dioxide (CO_2, green), methane (CH_4, orange) and nitrous oxide (N_2O, red) determined from ice core data (dots) and from direct atmospheric measurements (lines). Indicators: **(d)** Global anthropogenic CO_2 emissions from forestry and other land use as well as from burning of fossil fuel, cement production and flaring. Cumulative emissions of CO_2 from these sources and their uncertainties are shown as bars and whiskers, respectively, on the right hand side. The global effects of the accumulation of CH_4 and N_2O emissions are shown in panel c. Greenhouse gas emission data from 1970 to 2010 are shown in Figure SPM.2.

SPM 1.2 Causes of climate change

Anthropogenic 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, have been detected throughout the climate system and are *extremely likely* to have been the dominant cause of the observed warming since the mid-20th century. *{1.2, 1.3.1}*

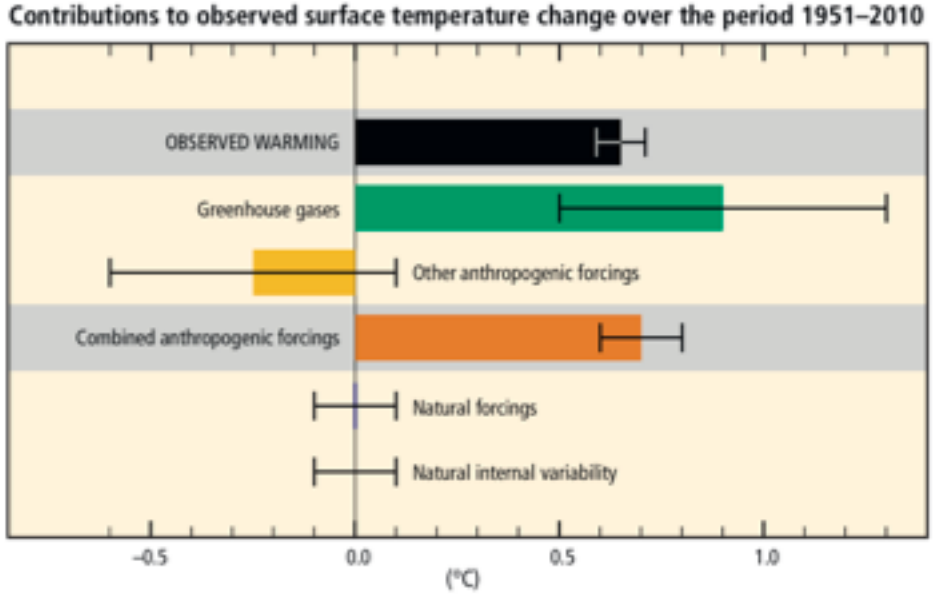


Figure SPM.3 | Assessed *likely* ranges (whiskers) and their mid-points (bars) for warming trends over the 1951–2010 period from well-mixed greenhouse gases, other anthropogenic forcings (including the cooling effect of aerosols and the effect of land use change), combined anthropogenic forcings, natural forcings and natural internal climate variability (which is the element of climate variability that arises spontaneously within the climate system even in the absence of forcings). The observed surface temperature change is shown in black, with the 5 to 95% uncertainty range due to observational uncertainty. The attributed warming ranges (colours) are based on observations combined with climate model simulations, in order to estimate the contribution of an individual external forcing to the observed warming. The contribution from the combined anthropogenic forcings can be estimated with less uncertainty than the contributions from greenhouse gases and from other anthropogenic forcings separately. This is because these two contributions partially compensate, resulting in a combined signal that is better constrained by observations. *(Figure 1.9)*

SPM 1.3 Impacts of climate change

In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. Impacts are due to observed climate change, irrespective of its cause, indicating the sensitivity of natural and human systems to changing climate. *{1.3.2}*

SPM 1.4 Extreme events

Changes in many extreme weather and climate events have been observed since about 1950. Some of these changes have been linked to human influences, including a decrease in cold temperature extremes, an increase in warm temperature extremes, an increase in extreme high sea levels and an increase in the number of heavy precipitation events in a number of regions. *{1.4}*

Climate change thus far is a fact. Human impacts are a fact.

What can we do about climate change?

To register: your_town county clerk

- Vote! Encourage your elected officials to do what *you* want
- Reduce travel-related carbon emissions: Walk, bike, carpool, take public transportation rather than driving a single-occupant car
- Save energy at home and work: use energy-saving light bulbs, turn out lights when leave room, take shorter showers, turn up air conditioning, turn down heat, unplug electronics when not in use
- Be a smart shopper: buy energy-efficient devices, consume less by buying less, use reusable bags, go vegetarian (?) each meat-eating American produces 1.5 tons more greenhouse gases? Deforestation for herds? How far has your food travelled?
- Consider renewable energies such as solar power at home/work/school
- Recycle and compost at home, work, school, in your neighborhood and town
- Go green: grow your own food, plant trees

The Future…

SPM 2. Future Climate Changes, Risks and Impacts

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. *{2}*

SPM 2.1 Key drivers of future climate

Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond. Projections of greenhouse gas emissions vary over a wide range, depending on both socio-economic development and climate policy. *{2.1}*

The Future …

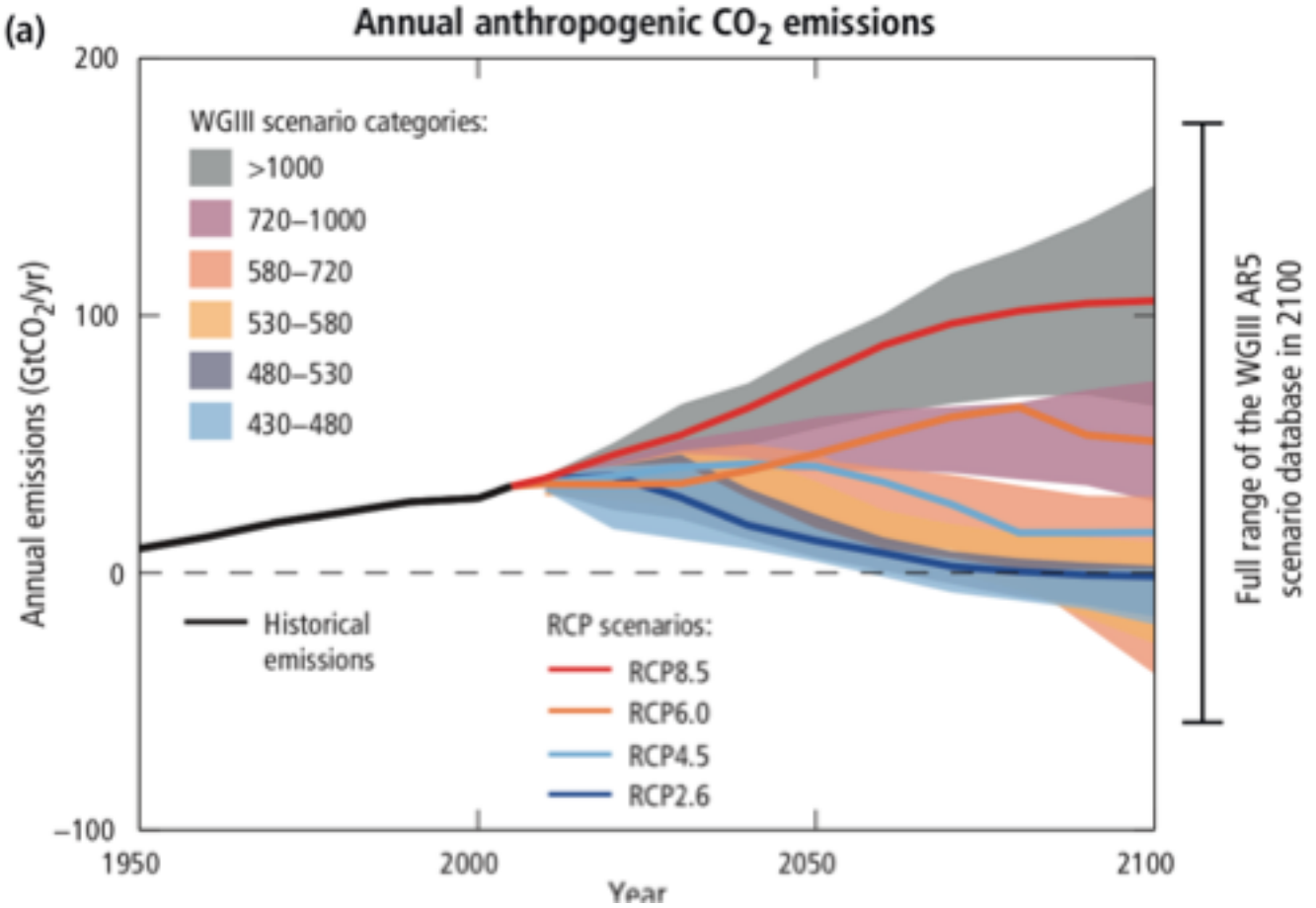


Figure SPM.5 | (a) Emissions of carbon dioxide (CO_2) alone in the Representative Concentration Pathways (RCPs) (lines) and the associated scenario categories used in WGIII (coloured areas show 5 to 95% range). The WGIII scenario categories summarize the wide range of emission scenarios published in the scientific literature and are defined on the basis of CO_2-eq concentration levels (in ppm) in 2100. The time series of other greenhouse gas emissions are shown in Box 2.2, Figure 1. **(b)** Global mean surface temperature increase at the time global CO_2 emissions reach a given net cumulative total, plotted

The Future…

SPM 2.2 Projected changes in the climate system

Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is *very likely* that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise. *{2.2}*

The projected changes in Section SPM 2.2 are for 2081–2100 relative to 1986–2005, unless otherwise indicated.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties

Table 1. Likelihood Scale

Term*	Likelihood of the Outcome
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

The Future …

Projections

Projections are not fact.

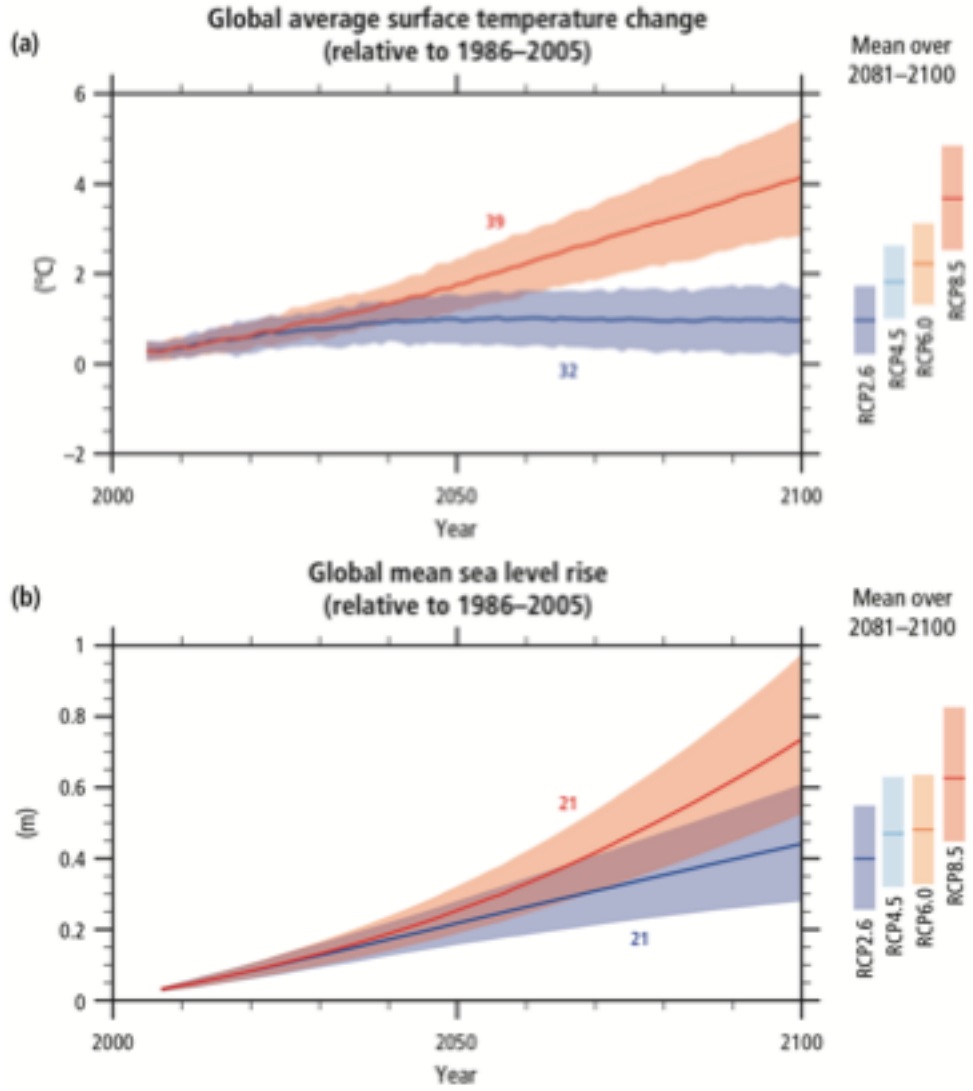
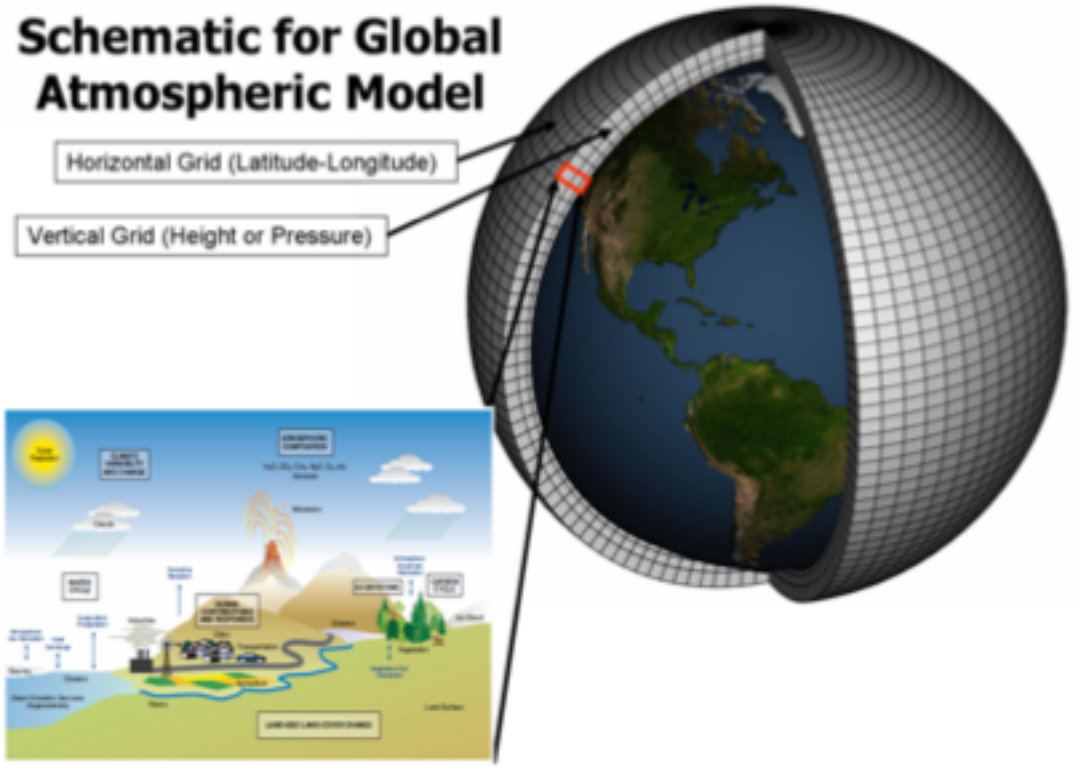


Figure SPM.6 | Global average surface temperature change **(a)** and global mean sea level rise[10] **(b)** from 2006 to 2100 as determined by multi-model simulations. All changes are relative to 1986–2005. Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). The mean and associated uncertainties averaged over 2081–2100 are given for all RCP scenarios as coloured vertical bars at the right hand side of each panel. The number of Coupled Model Intercomparison Project Phase 5 (CMIP5) models used to calculate the multi-model mean is indicated. *[2.2, Figure 2.1]*

How do scientists estimate/predict future climate? Climate Models

- Systems of differential equations
- Based on laws of physics, fluid motion, chemistry
- Coordinate system divides planet into 3-d grid
- Winds, heat transfer, solar radiation, relative humidity, surface hydrology calc in each grid cell
- Interactions with neighboring cells are used to calc atmospheric properties in near and far *future*



2 main types:

- Global Atmospheric Models
- Earth System Models=Global Atmospheric Model *coupled* with Ocean Model, Land Model, Land-Ice Model, and/or Sea-Ice Model

Climate Model Experiments: Ensembles

Run slightly different versions of the model multiple times…

- Different initial conditions (e.g. random temperature perturbations < 0.1 º)
- Different physics parameters

and/or

- Different forcings (e.g. RCP2.6 or RCP8.5)

depending on what experiment is testing
Results: slightly different Earths

Attribution, Predictability & Assessment (APA)

Understand the physical factors that cause:

- Observed regional climate trends
- Observed seasonal climate trends
- High-impact/extreme weather events
- High-impact/extreme climate events

What are the large-scale drivers that influence extreme events?

Provide knowledge for climate risk management & adaptation

Use a variety of climate models including

NCAR's Community Earth System Model (CESM1) Large Ensemble (LENS)

- 40-member ensemble
- Years 1920-2100
- fully-coupled CESM1
- RCP8.5 after 2005
- Publicly available http://www.cesm.ucar.edu/projects/community-projects/LENS/

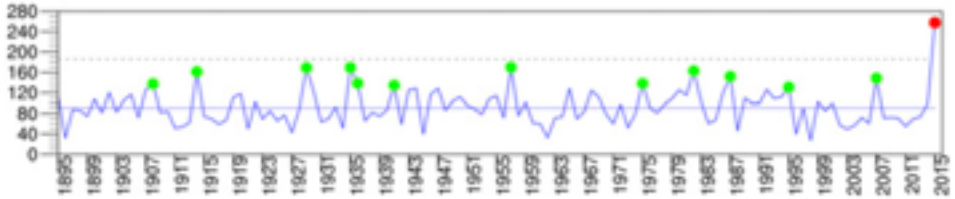
Example APA extreme event Project:

Diagnosing Human-Induced Dynamic and Thermodynamic Drivers of Extreme Rainfall

L. Cheng, M. Hoerling, L. Smith, J. Eischeid, *Journal of Climate*, Feb 2018

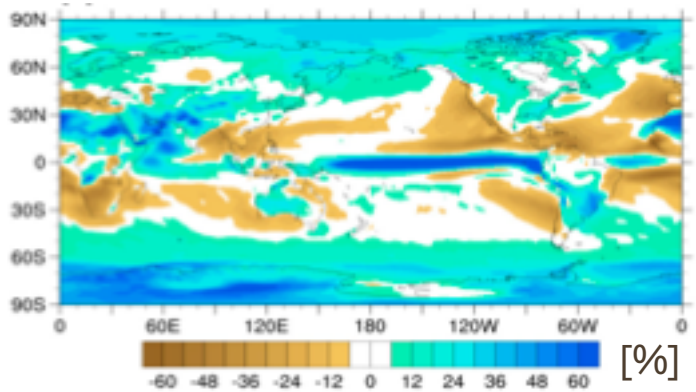
Abstract: Factors responsible for extreme monthly rainfall over Texas and Oklahoma during May 2015 are assessed…

Step 1: Observations: TX/OK precip
NOAA U.S. Climate Division Data



[mm]

Model data
Averaged composites CESM1 LENS precip
2050-80 Mays minus 1920-50 Mays.
→Simulated changes in mean climate
6% more TX/OK rainfall



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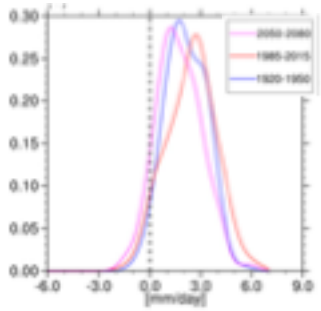
Statistical analyses
Model data: CESM1 LENS

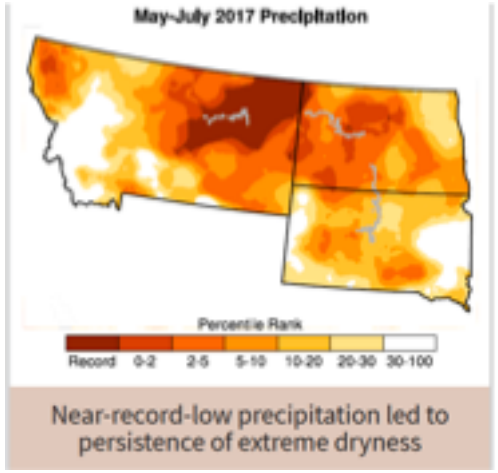
e.g. Probability Density Function
May El Nino TX/OK precip



Conclusions: El Nino alone was found to be a critical condition for such an extreme event to occur in 2015 TX/OK.
…the observed TX/OK May 2015 event was not made more intense or become more likely as a result of human-induced climate change over the past century

Example APA extreme event Project: Drought in the U.S. Great Plains MJJ 2017

Work in progress…



Step 1: Observations

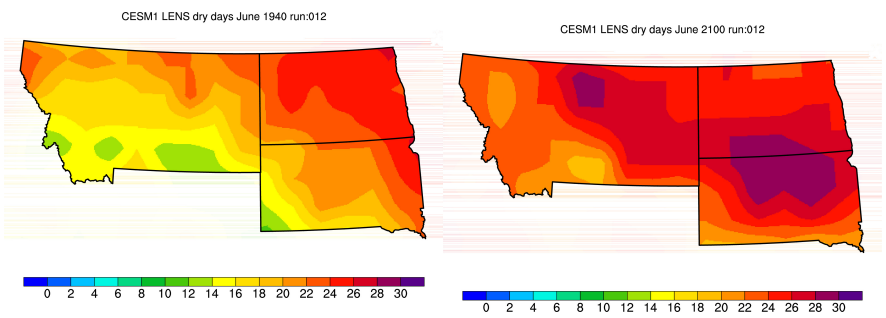
Observational Data: Drought due to low precipitation

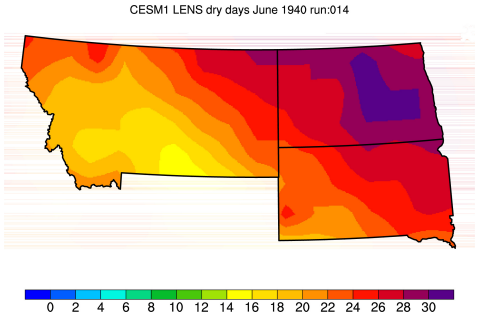
NOAA National Centers of Environmental Info (NCEI) data

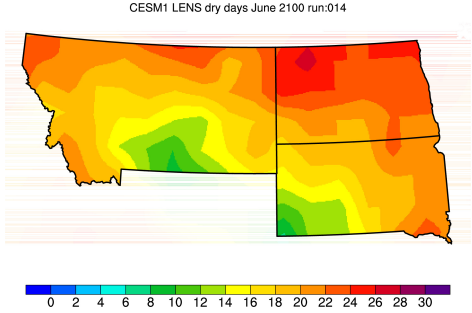
Why was there low precip?
Climate Change? ENSO? Natural Variability?

Model Data: CESM1 LENS

Preliminary figures:







➔ Low precip probably not due to climate change

Stay tuned for more results…

How do Climate Change and Critical Thinking relate to each other?

Climate Change Controversy! For example:

HOAX?

Some people don't believe climate is changing and/or that humans are responsible

Are these people using their critical thinking skills?

Opinions of the General public

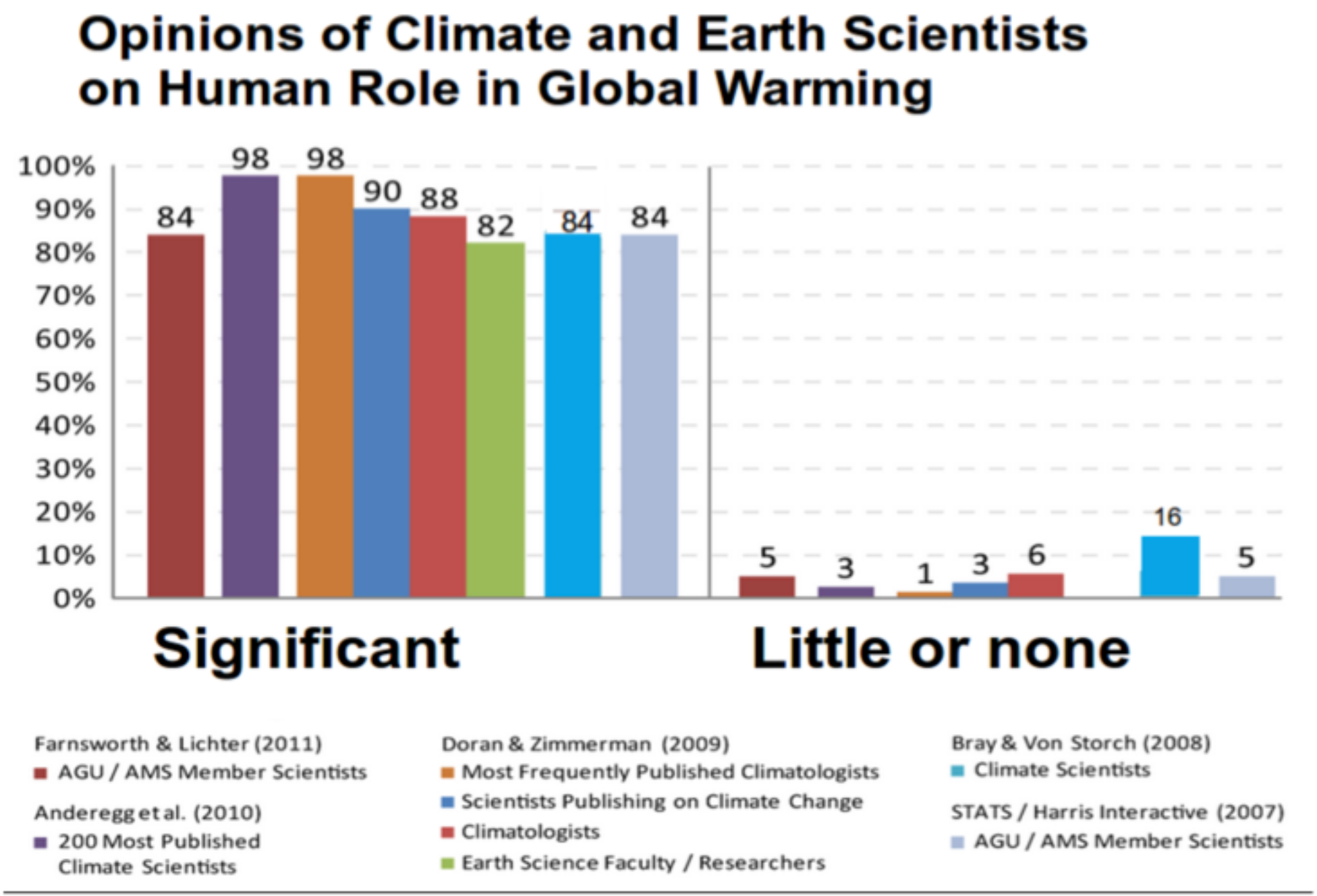
Q47[1]. Recently, you may have noticed that global warming has been getting some attention in the news. Global warming refers to the idea that the world's average temperature has been increasing over the past 150 years, may be increasing more in the future, and that the world's climate may change as a result. What do you think? Do you think that global warming is happening?

	May 2011	June 2010	Jan 2010	Nov 2008
Yes	64	61	57	71
No	18	18	20	10
Don't Know	18	21	23	19

Q50. Assuming global warming is happening, do you think it is…

	May 2011	June 2010	Jan 2010	Nov 2008
Caused mostly by human activities	47	50	47	57
Caused mostly by natural changes in the environment	35	34	36	32
None of the above because global warming isn't happening	8	6	9	4
Caused by both human activities and natural changes (volunteered)	8	7	6	5
Other	1	1	1	1
Don't know (volunteered)	1	1	1	1

Opinions of Scientists



Bulletin of Science, Technology & Society

Climate Scientists Virtually Unanimous

Anthropogenic Global Warming Is True

James Lawrence Powell

First Published March 28, 2016 | Research Article | Check for updates

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Article information

Altmetric 287

Abstract

The extent of the consensus among scientists on anthropogenic global warming (AGW) has the potential to influence public opinion and the attitude of political leaders and thus matters greatly to society. The history of science demonstrates that if we wish to judge the level of a scientific consensus and whether the consensus position is likely to be correct, the only reliable source is the peer-reviewed literature. During 2013 and 2014, only 4 of 69,406 authors of peer-reviewed articles on global warming, 0.0058% or 1 in 17,352, rejected AGW. Thus, the consensus on AGW among publishing scientists is above 99.99%, verging on unanimity. The U.S. House of Representatives holds 40 times as many global warming rejecters as are found among the authors of scientific articles. The peer-reviewed literature contains no convincing evidence against AGW.

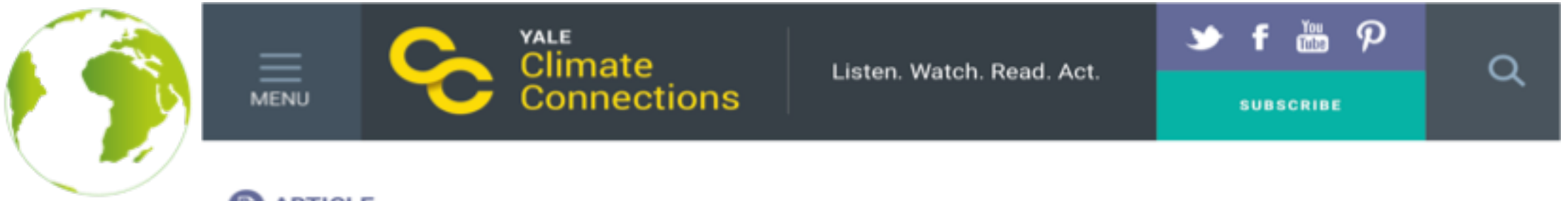
- Scientists believe
- Do *you* believe? If so, why? If not, why?
  explicit bias, implicit bias…
- What do you (critically) *think* of all this belief?
- Recall :The Scientific Method

Ask a question, do background research, construct hypothesis, test with experiment, analyze data and draw conclusions. Do results support hypothesis? Communicate results.

- Technically, *belief* is not part of science…

What responsibilities do informed, educated people have regarding climate change?

Engage/discuss/interact…



ARTICLE

Finding common ground amid climate controversy

By Karin Kirk on Apr 4, 2018

Generating productive conversations - ranters need not apply - and finding shared values on climate issues IS possible.

- Forget the tirades, quell the yelling
- Not so divided as you might think
- Frame solutions to show immediate tangible economic benefits
- Engage as a fallible inquisitive human not an all-knowing scientist
- Acknowledge valid questions; give answers in plain English

Audience Take-Aways

- It is very important to develop and utilize critical thinking skills
- Learn about & be aware of your explicit and implicit biases
- Earth's weather and climate are due to the Sun
- Climate is changing
- Thus far, humans *have* had an effect on climate
- The future is less certain…

- Consider helping your friends/relatives develop their critical thinking skills and learn more about climate

Thanks for listening!

Questions?

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University of Colorado **Boulder**