Understanding Our *Changing* Climate

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10 February 2018
Understanding Our *Changing* Climate

- What is the greenhouse effect?
  - Natural and anthropogenic
- Why is the climate changing?
  - Role of human activity
- What is happening now?
  - Many independent warming indicators
- How do we know humans are responsible?
  - Basic physics
  - Complex models
- What will happen in the future?
What is the Greenhouse Effect?

Earth's Greenhouse Effect

Greenhouse gases let the sun's short wave radiation (visible light) reach the earth, but trap some of the long wave (infrared or heat) radiation coming from the warm earth.

Adapted from http://www.dec.ny.gov/images/administration_images/greenhouse.jpg
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Incoming solar radiation (short wave)

Reflected by the earth and its atmosphere

Infrared radiation (heat) emitted from earth's surface (long wave)

Atmosphere Carbon Store (Troposphere)

Warms the earth's surface

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What is the Greenhouse Effect?

Greenhouse gases such as CO₂ absorb and emit this infrared radiation.
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What is the Greenhouse Effect?
Natural and essential aspect of the climate

Greenhouse gases such as CO$_2$ absorb and emit this infrared radiation

Increased radiation warms the surface

Adapted from http://www.dec.ny.gov/images/administration_images/greenhouse.jpg
Why is the Climate Changing?

Concentrations of Greenhouse Gases from 0 to 2005

- **Carbon Dioxide (CO₂)**
- **Methane (CH₄)**
- **Nitrous Oxide (N₂O)**

![Graph showing concentrations of greenhouse gases from 0 to 2005.](image_url)
Why is the Climate Changing?
Why is the Climate Changing?

Atmospheric Carbon Dioxide Levels

2100 Higher Scenario

2100 Lower Scenario

2011 Observed

Historical Range
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- Atmosphere absorbs more IR, less escapes to space
- Greenhouse gases in atmosphere absorb and emit even more infrared radiation, further warming the surface

Adapted from http://www.dec.ny.gov/images/administration_images/greenhouse.jpg
Greenhouse gases in the atmosphere absorb and emit even more infrared radiation, further warming the surface.

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Why is the Climate Changing?...
... but what about uncertainty?
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Greenhouse Effect Summary

• Potential for emitted CO$_2$ to alter climate has been recognized for a long time
  – 1824: Joseph Fourier establishes existence of natural greenhouse effect
  – 1859: John Tyndall confirms heat-trapping properties of greenhouse gases
  – 1890: Svante Arrhenius computes first estimate of expected global temperature increase from fossil fuel use

• Simple physics tells us increasing CO$_2$ should increase temperature
  – NOT having the temperature go up would be the odder result
  – Climate system is extremely complex, so odd results are possible
    • Does not appear to be the case
What is happening now?
Global Temperature is Increasing

Global Land and Ocean Temperature Temperature Anomalies

Anomaly (°F)

Year

1880 1900 1920 1940 1960 1980 2000

1880-2017

data from http://www.ncdc.noaa.gov/cmb-faq/anomalies.php#mean
What is happening now?
Global Temperature is Increasing

Global Land and Ocean Temperature Temperature Anomalies

"Pause"

Year
1880-2017

Anomaly (°F)
-0.8
-0.4
0.0
0.4
0.8
1.2
1.6
2.0

data from http://www.ncdc.noaa.gov/cmb-faq/anomalies.php#mean
What is happening now?
Global Temperature is Increasing

![Graph showing decadal temperature anomalies from 1890 to 2010. The y-axis represents anomaly in °F, and the x-axis represents decades. The graph shows a significant increase in temperature anomalies from 1990 onwards.]

Is the temperature really increasing? How do we know?

Ten Indicators of a Warming World

- Air Temperature Near Surface (Troposphere)
- Glaciers and Ice Sheets
- Snow Cover
- Temperature Over Land
- Sea Level
- Ocean Heat Content
- Temperature Over Oceans
- Sea Surface Temperature
- Water Vapor
- Sea Ice

National Climate Assessment 2014: Fig 2.1
Multiple independent observations consistent with a warming planet

Is the temperature really increasing? How do we know?

Ten Indicators of a Warming World

National Climate Assessment 2014: Fig 2.1
What is happening now?
Sea Level is Rising

Crisfield, Maryland, at high tide
© 2013 Greg Kahn
What is happening now?
Sea Ice is Disappearing

Arctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)
What is happening now?
Trees Are Blooming Earlier

Kyoto Cherry Blossom Flowering Time

Lowess smooth, bandwidth 0.2. Data from http://atmenv.envi.osakafu-u.ac.jp/aono/kyophenotemp4/
What is happening now?
Trees Are Blooming Earlier

Cherry blossom peak bloom dates in Washington, D.C. and Kyoto (1921-2017)
How do we know humans are responsible for these changes?

Climate models represent multiple physical processes and their interactions numerically.

Supercomputers are used to solve resulting equations.

Require hundreds of hours on 10’s of thousands of processors.

Not without flaws!

Allow for “What if?” questions:
- What if greenhouse gases had not increased?
- What if they continue to increase?
Based on our best understanding of the climate system at this time, recent warming trends cannot be explained by natural forcing alone.
What Happens Next?

Mostly, it depends on us.

Aggressive emission reductions still lead to additional warming, but only about another 1 °F.

Worst case scenario does not really bear thinking about...
What Happens Next? Severity of Hottest Days Will Increase

Projected Temperature Change of Hottest Days

Rapid Emissions Reductions (RCP 2.6)

Continued Emissions Increases (RCP 8.5)

Temperature Change (°F)

3 4 5 6 7 8 9 10 11 12 13 14 15

NCA 2.20

10+ (!) degree increase for Virginia under worst-case scenario
Summary

• Climate change is happening now, and will continue into the future
  – Human activity is amplifying planet’s natural greenhouse effect
  – Multiple indicators pointing to a warming planet
  – We (hopefully) still have time to avoid the worst effects

• What do we do now?
  – Reduce, reduce, reduce
    • Mitigation needs to be part of any strategy. The sooner we start, the less painful it will be
  – Benefits beyond carbon reduction
    • Improved air-quality
    • Energy independence
  – We do not want to adapt to a worst-case scenario world
CLIMATE SUMMIT

What if it's a big hoax and we create a better world for nothing?

- Energy Independence
- Preserve Rainforests
- Sustainability
- Green Jobs
- Livable Cities
- Renewables
- Clean Water, Air
- Healthy Children
- etc. etc.