Climate Change and Pennsylvania's Forests

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Climate 101

- It’s warming (yes, it is)
- It’s us (yes, it is)
- We’re sure (very sure)
- It’s bad
  - But not so much for Pennsylvania
- We can (and should) mitigate it
- We will have to adapt to it

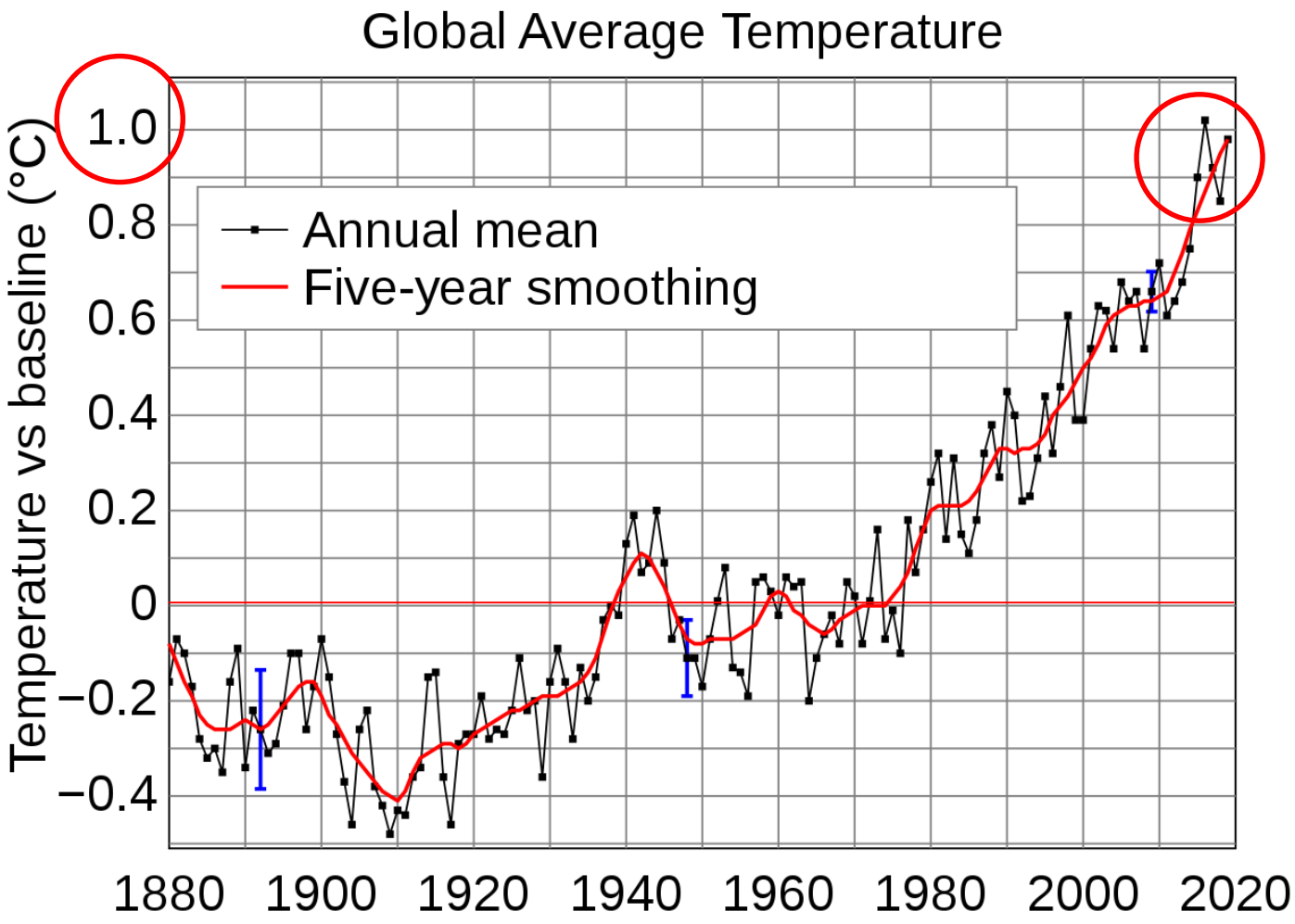
Outline

- How sure are we about climate change?
- How Pennsylvania's climate is projected to change
- General risks for Pennsylvanians
- Projected impacts to Pennsylvania's forest ecosystems
- Mitigation and Adaptation

How sure are we about climate change?

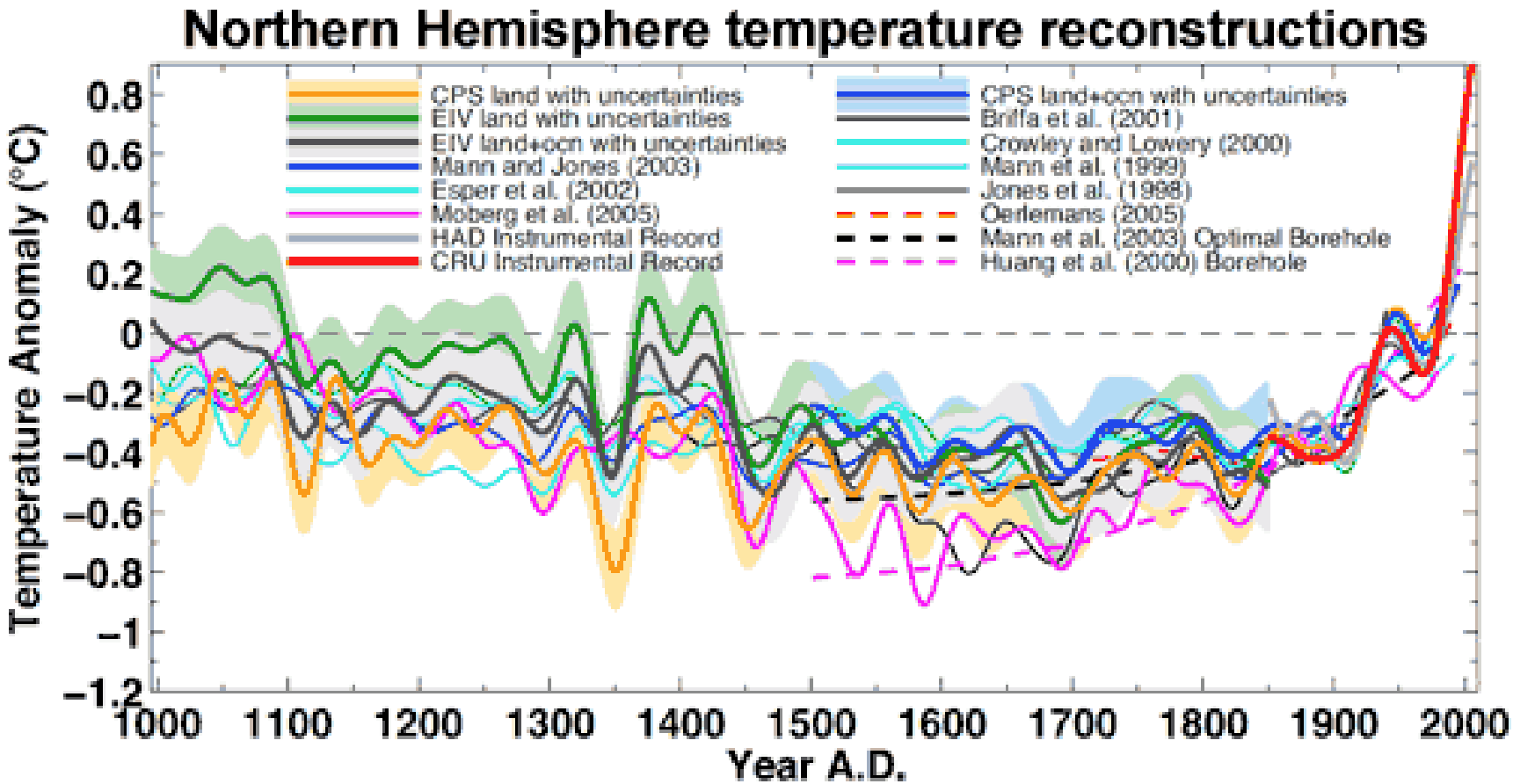
- There is very little uncertainty about the more general projections:
  - Temperatures are rising and they will continue to rise.
  - The amount of moisture in the atmosphere is increasing and will continue to increase.
  - With additional heat and moisture in the atmosphere, storms will be more intense.
  - Sea level is rising and will continue to rise.
  - People are being and will continue to be displaced.
  - Ecosystems are and will continue to be disrupted.
- We understand remarkably well how the Earth's climate system works.
  - Of course, there's a lot we don't know
  - Biggest uncertainty: we don't know what people will do.

Is the Climate Warming?



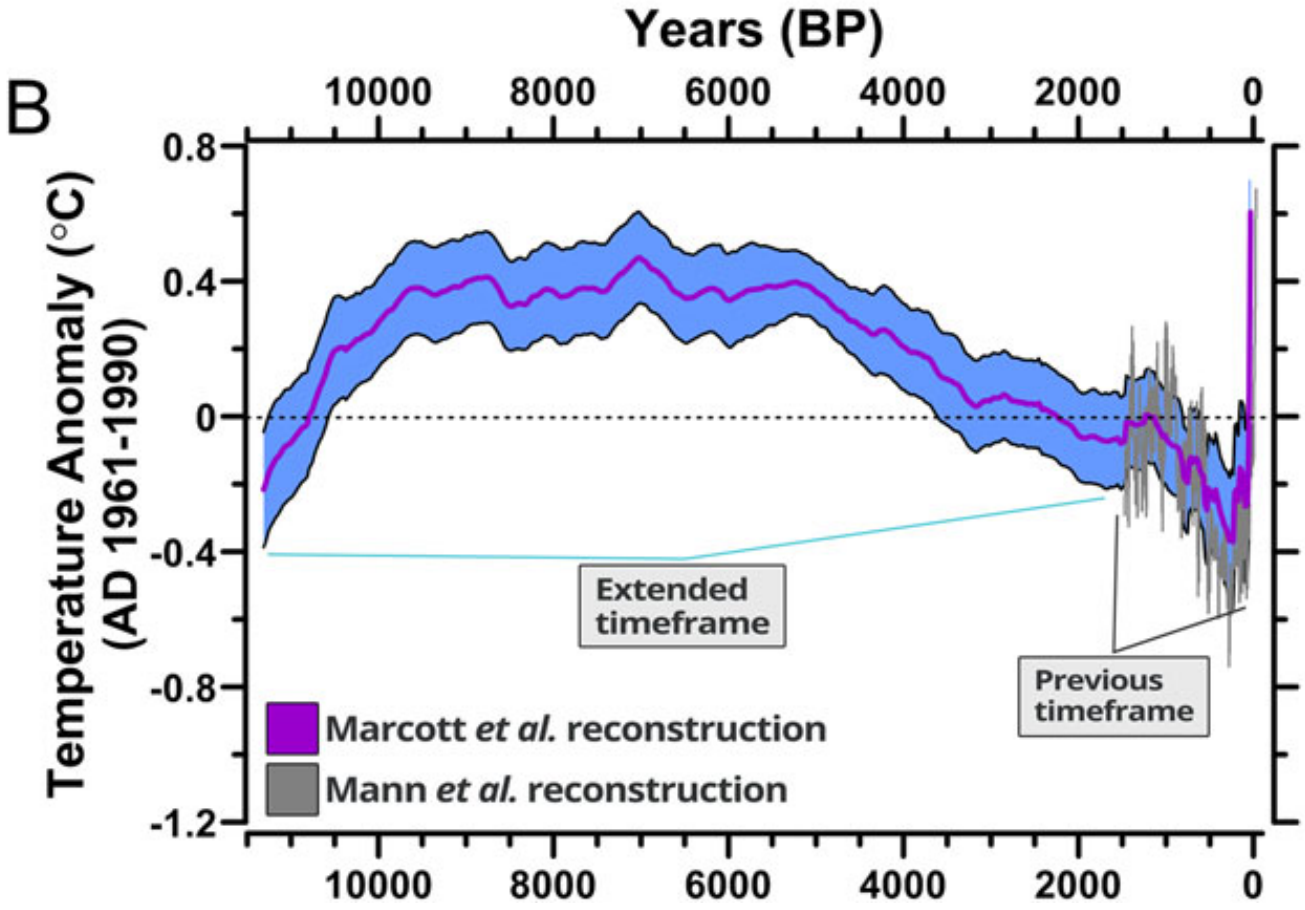
Global mean surface temperature change since 1880. Baseline temperature[1] is about 14 °C. Source: NASA GISS

Is the Climate Warming?



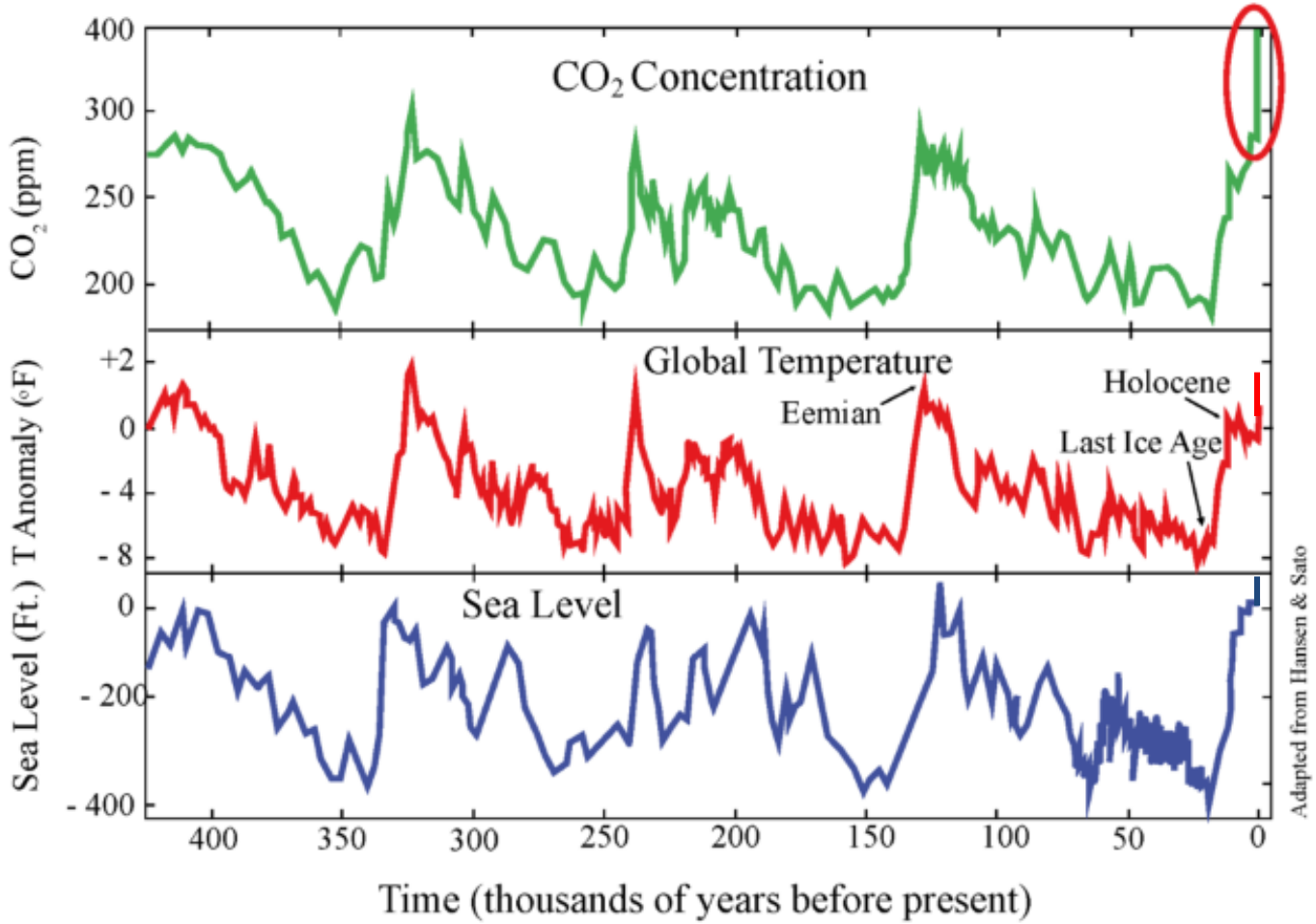
Composite Northern Hemisphere land and land plus ocean temperature reconstructions and estimated 95% confidence intervals. Shown for comparison are published Northern Hemisphere reconstructions (Mann 2008).

Is the Climate Warming?



Marcott et al. 2013. A Reconstruction of Regional and Global Temperature for the Past 11,300 Years. Science 8 March 2013: Vol. 339 no. 6124 pp. 1198-1201.

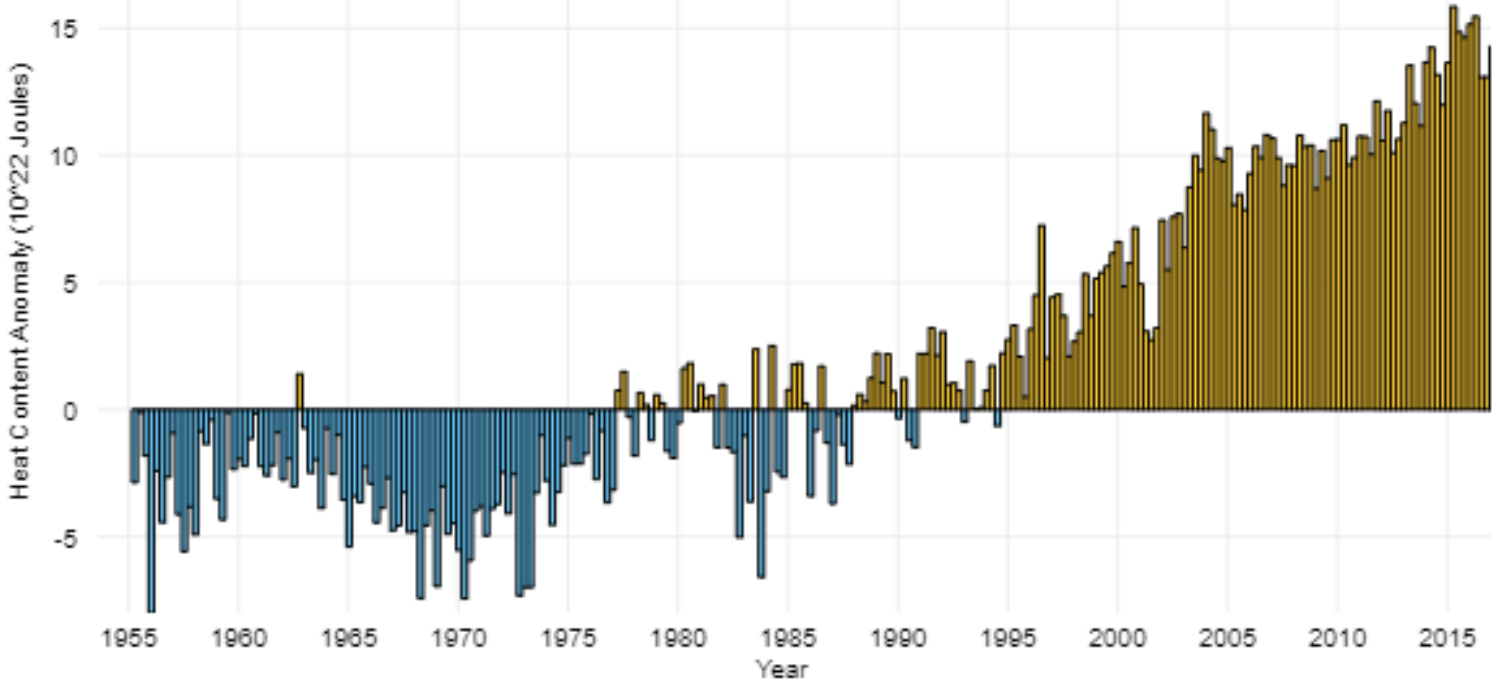
Is the Climate Warming?



Source: John Englander, 2017, Single Image Proves Human-Caused Global Warming
https://www.johnenglander.net/single-image-proves-human-caused-global-warming/

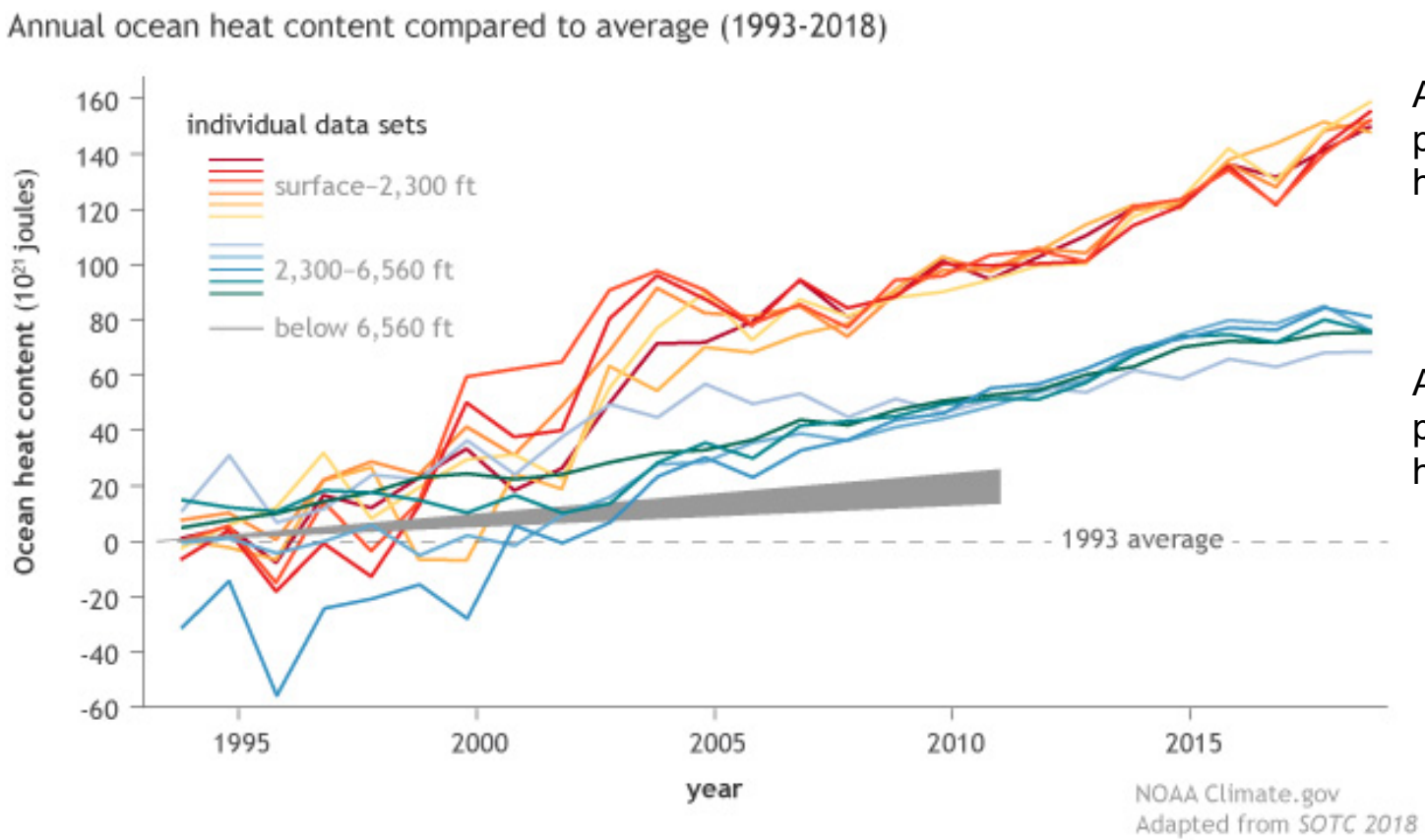
Climate Change Indicators: Ocean Heat

More than 90 percent of the warming that has happened on Earth over the past 50 years has occurred in the ocean.



Source: Dahlman, LuAnn and Rebecca Lindsey. February 13, 2020. Climate Change: Ocean Heat Content
https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content

Climate Change Indicators: Ocean Heat

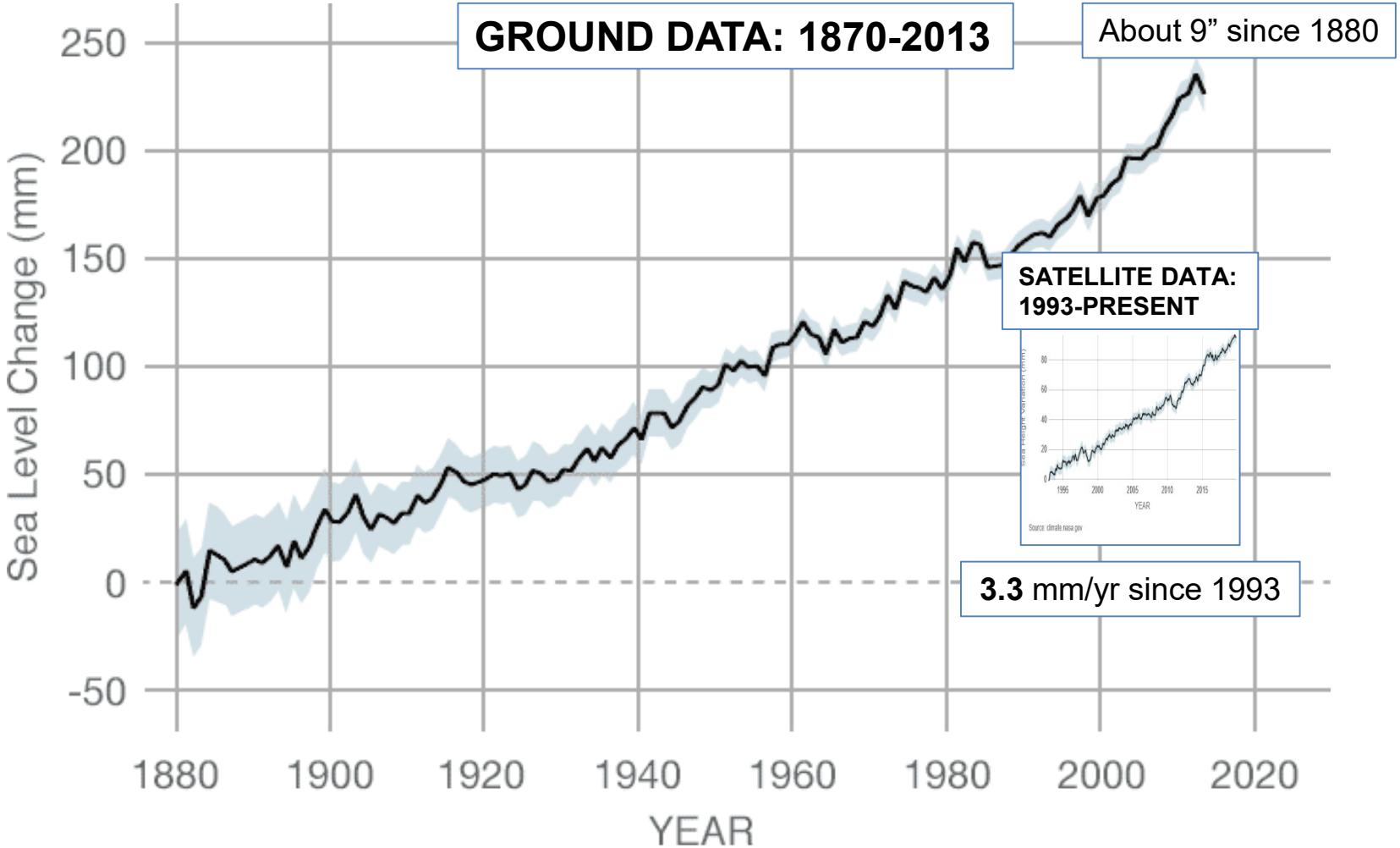


About 60 percent of the heat

About 30 percent of the heat

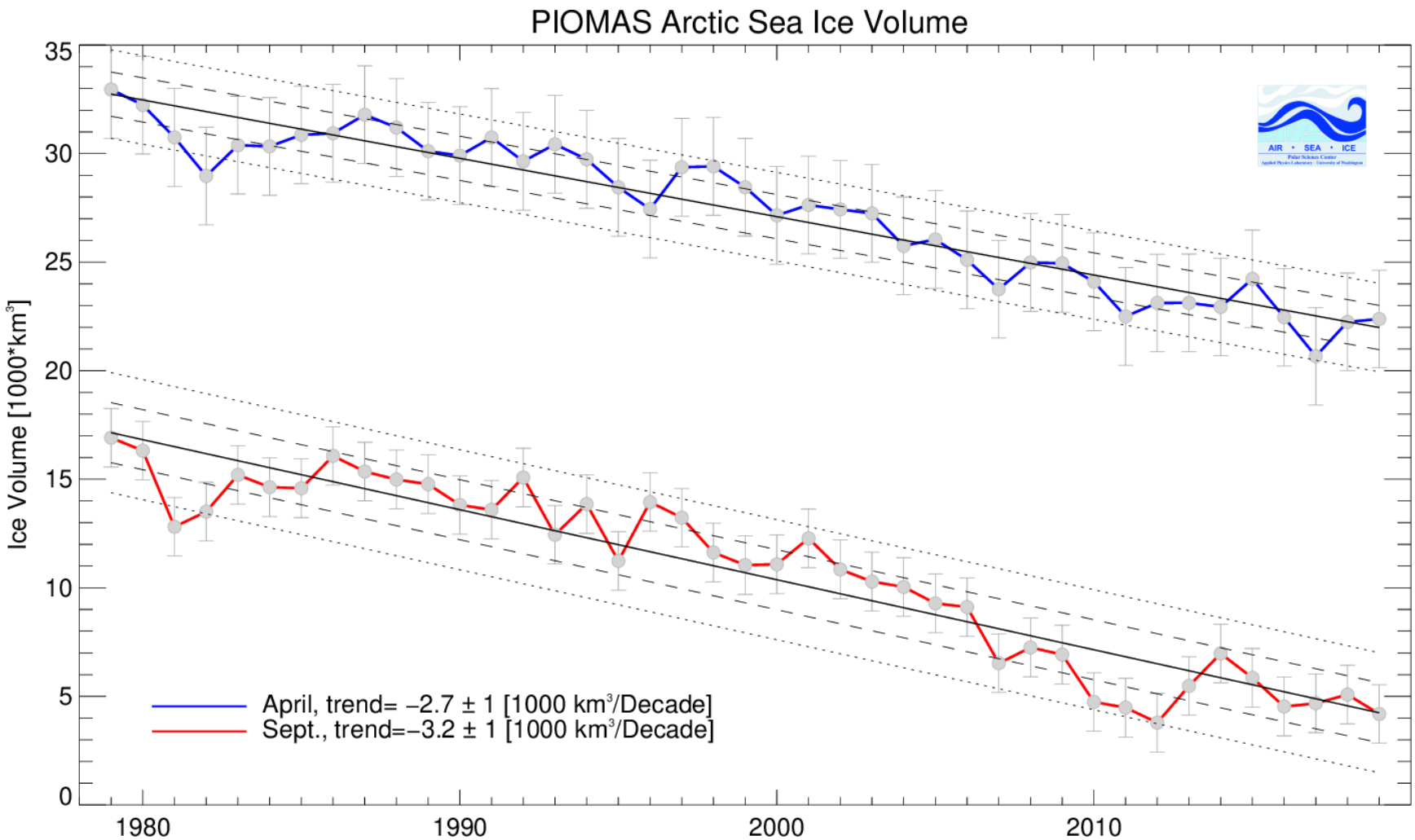
Source: Dahlman, LuAnn and Rebecca Lindsey. February 13, 2020. Climate Change: Ocean Heat Content
https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content

Climate Change Indicators: Sea Level Rise



Source: https://climate.nasa.gov/vital-signs/sea-level/

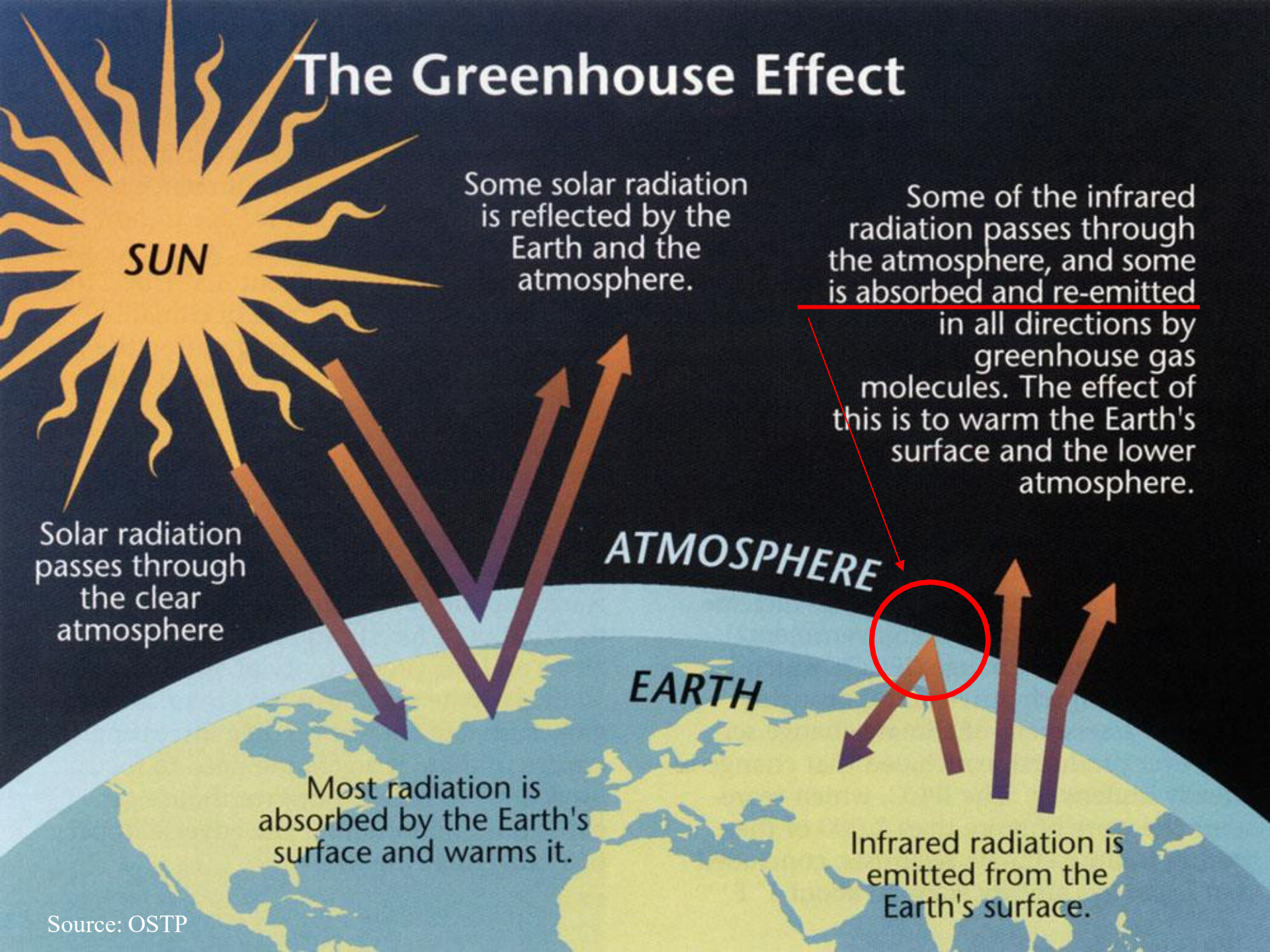
Arctic Sea Ice Volume Trends



Source: Polar Science Center, Applied Physics Laboratory, University of Washington
http://psc.apl.uw.edu/research/projects/arctic-sea-ice-volume-anomaly/

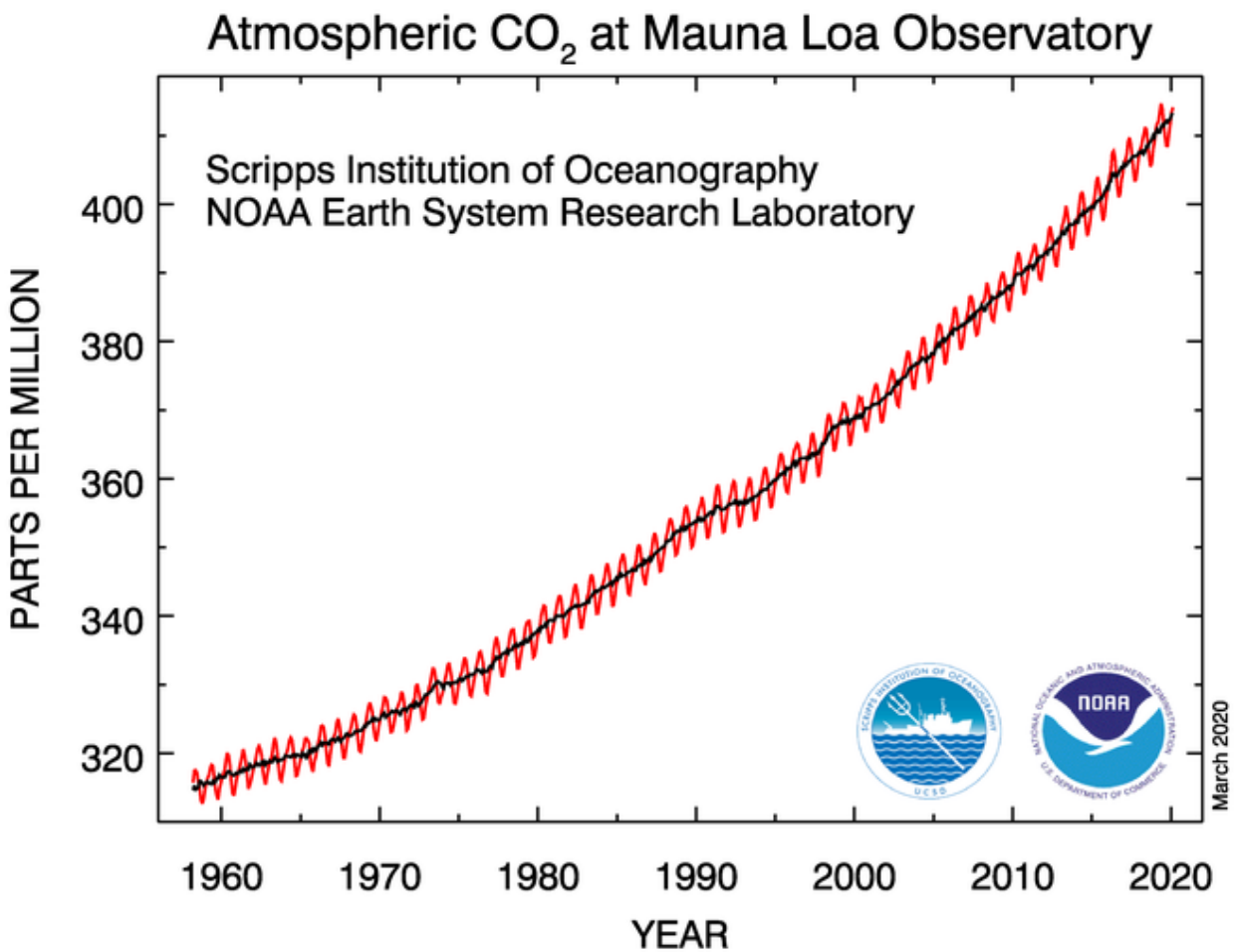
78% nitrogen, N_2
21% oxygen, O_2
1% other gases:
argon 0.9%, water vapor (H_20), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O)

Greenhouse gases are minor constituents of Earth's atmosphere, present at very low concentrations, but have a major influence on climate.


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere, and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

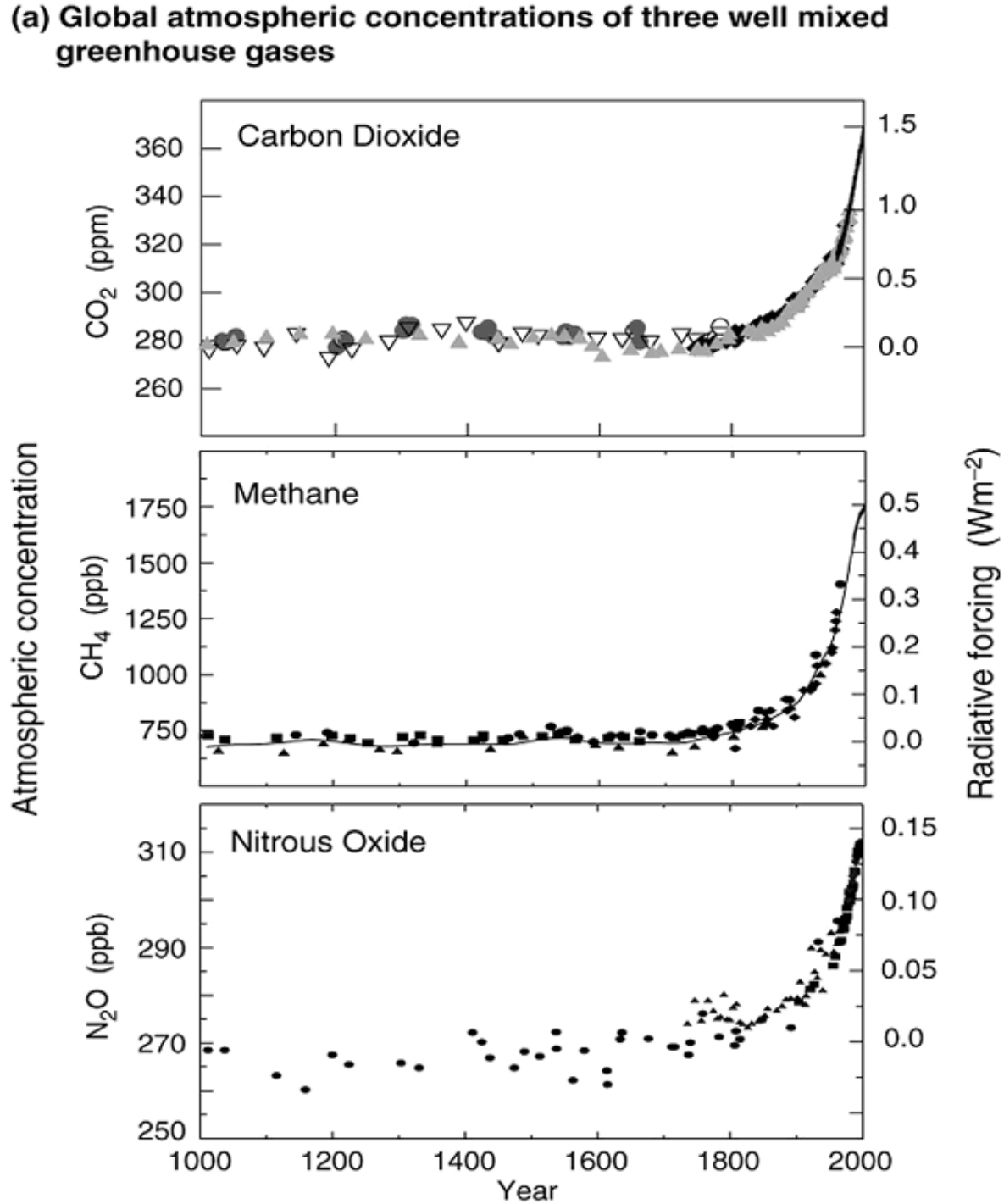
Source: OSTP

So how has the level of CO_2 changed?



NOAA Earth Systems Research Laboratory
(http://www.esrl.noaa.gov/gmd/ccgg/trends/full.html)

What about the other GHGs?



Uncertainty Applies in Both Directions

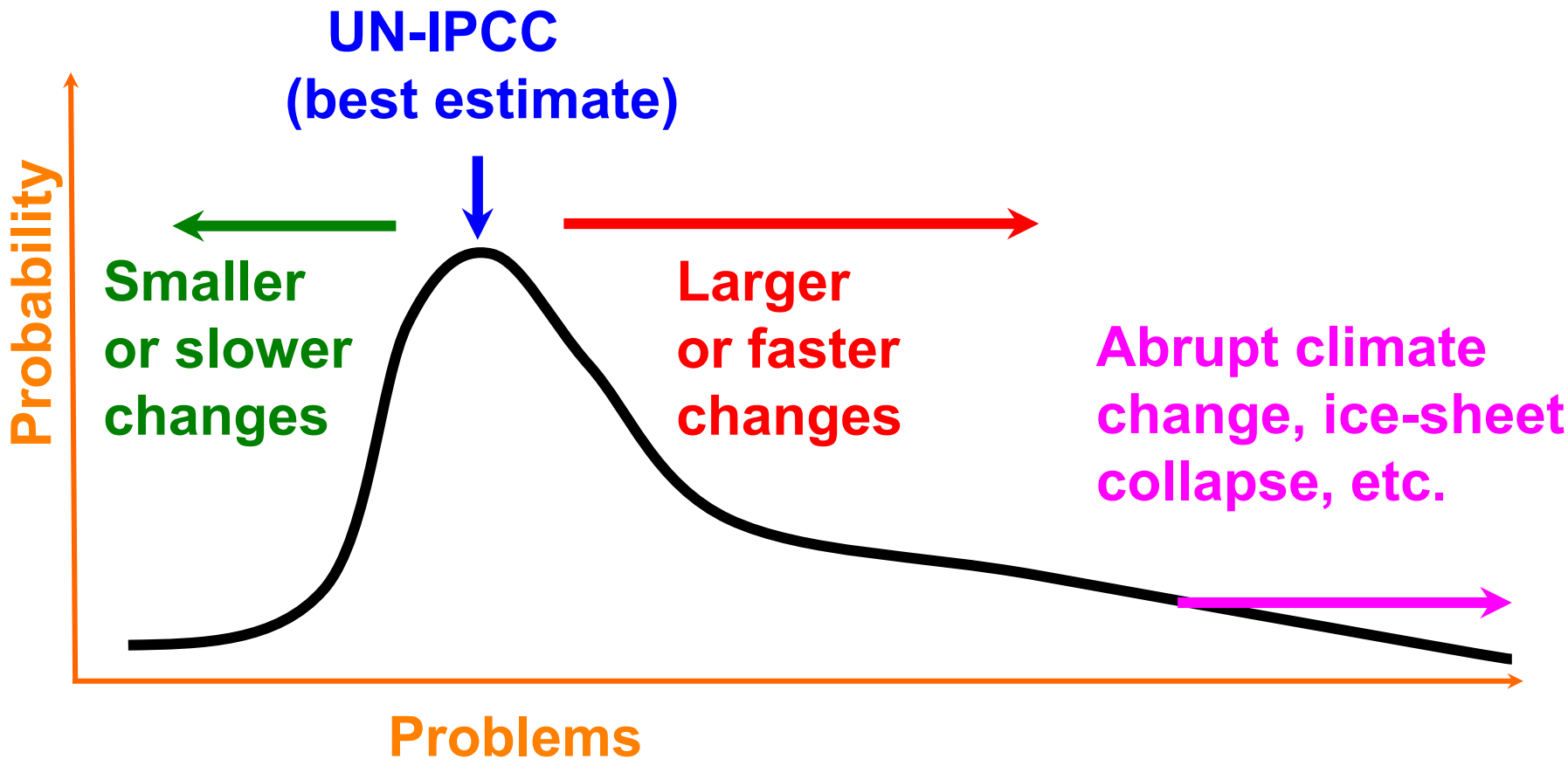


Figure adapted from a talk by Richard Alley.

How is Pennsylvania's climate projected to change?

- Pennsylvania has warmed by more than 1°C over the past 110 years.
  - That's 1.8°F.
  - Most of this warming is due to an increase of heat-trapping gases in the atmosphere from human activities.
  - The rate of warming has accelerated in the past 30 years.
- Pennsylvania will continue to warm.
- If the trends in heat-trapping gas emissions continue, the temperature very likely will be 1.9-4.3°C higher by mid-century (2041-2070) than it was in the late 20th century (1971-2000).
  - That's 3.4-7.7°F – by mid-century…
  - That's at least 2X the amount of change in the past century.
  - Reduced emissions of heat-trapping gases would mitigate temperature increases.

How is Pennsylvania's climate projected to change?

- Pennsylvania's climate has and will continue to become wetter.
- If the current trends in heat-trapping gas emissions continue, it is very likely that annual precipitation will be 0-16% higher by mid-century (2041-2070) than it was in the late 20th century (1971-2000).
- Winter precipitation is likely to increase by 10%-20% by mid-century.
- The number of days with heavy rainfall is likely to continue to increase.

How is Pennsylvania's climate projected to change?

- The growing season will be longer.
  - 4-6 weeks longer by the end of the century
- Summer heat waves will be more frequent and more intense.
  - 20-30 more days per year over 90° by mid-century
- Stronger storms and floods will occur more frequently.
- Despite increases in overall precipitation levels, summer droughts could be more common.
  - Most of precipitation increase is in winter
  - More time in between precipitation events
  - More evaporation
- In other words, it will be <u>both</u> wetter and drier.

How will Pennsylvanians be affected?

- Energy consumption in Pennsylvania is likely to increase.
  - Increased demands for summer cooling are expected to outweigh decreased energy demands for winter heating.
- Flood risks will likely increase.
- Longer warm season for outdoor activities.
  - But high temperatures will occasionally limit outdoor activity.
- Wetter, warmer winters with less snow.
  - Commercial ski businesses likely will not remain economically viable.
- Increased demand for outdoor recreation opportunities.
  - Including water-based recreation at reservoirs and rivers.

How will Pennsylvanians be affected?

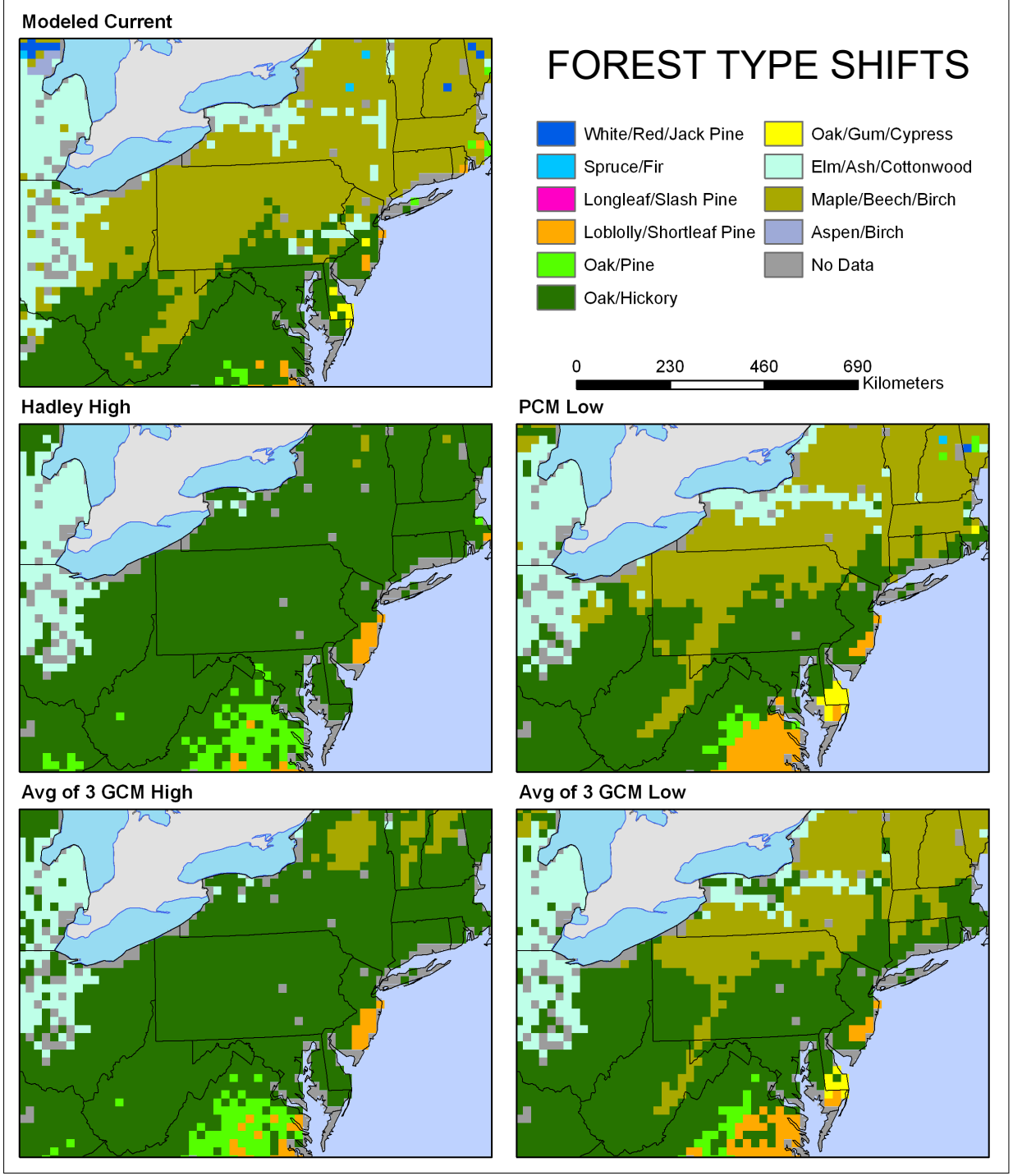
- Water temperatures are very likely to be higher and summer flows are likely to be lower in streams and rivers.
- Some rivers and streams will no longer be suited for cold-water fishing.
  - The Eastern Brook Trout population is very likely to decline and eventually be extirpated.
- Risks from insect-borne (e.g., Lyme Disease and West Nile Virus) and water-borne diseases (i.e., illness caused by pathogenic microorganisms in contaminated water) will likely increase.

How will Pennsylvanians be affected?

- Actually, Pennsylvania is relatively lucky when it comes to climate change.
- Impacts in other parts of the world will likely be much more serious than those projected for Pennsylvania.
- In the global society that exists today, Pennsylvanians will inevitably be affected by events triggered by impacts outside of Pennsylvania.
  - E.g., refugees, taxes to pay for infrastructure upgrades and repairs in coastal areas, increased global instability.

Projected Ecosystem Impacts of Climate Change in Pennsylvania

- As of now, little, if any change in the species composition of Pennsylvania's forest resource can be attributed with confidence to climate change.
- Suitable habitat for tree species in Pennsylvania is likely to move to higher latitudes and elevations.
- Mortality rates of species such as sugar maple, yellow or paper birch, and aspen that are at the southern extent of their ranges in Pennsylvania are likely to increase.
- In the near term, tree growth rates in Pennsylvania are likely to increase because of higher atmospheric carbon dioxide concentrations, longer growing seasons, and increased precipitation.


Modeled Current
FOREST TYPE SHIFTS
White/Red/Jack Pine
Spruce/Fir
Longleaf/Slash Pine
Loblolly/Shortleaf Pine
Oak/Pine
Oak/Hickory
Oak/Gum/Cypress
Elm/Ash/Cottonwood
Maple/Beech/Birch
Aspen/Birch
No Data
0
230
460
690
Kilometers
Hadley High
PCM Low
Avg of 3 GCM High
Avg of 3 GCM Low

Projected Ecosystem Impacts of Climate Change in Pennsylvania

- Likely to be extirpated: paper birch, quaking aspen, bigtooth aspen, yellow birch[1]
- Projected to decline substantially: American beech, black cherry, striped maple and eastern hemlock
- Projected to decline moderately under the cooler scenarios and substantially under the warmer scenarios: red maple, sugar maple, eastern white pine, sweet/black birch, white ash, and American basswood
  - This group contains the two most common species in the state: red maple and sweet/black birch

[1] Based on work done by Louis Iverson's USDA Forest Service lab

Projected Ecosystem Impacts of Climate Change in Pennsylvania

- Likely to be harmed only marginally or even benefit marginally: northern red oak, chestnut oak, yellow-poplar, and sassafras
- Habitat will improve moderately: pignut hickory, black walnut, and flowering dogwood, blackgum, white oak, and American elm
- Habitat improves substantially: mockernut hickory, black oak, silver maple and eastern redcedar
- Currently rare in Pennsylvania, but projected to gain substantial habitat: loblolly pine, shortleaf pine, common persimmon, red mulberry, black hickory, blackjack oak, winged elm, and post oak

[1] Based on work done by Louis Iverson's USDA Forest Service lab

Adaptation and Mitigation

- It's not a question of "either-or."
- Climate change is happening and will continue to happen.
  - So we will have to adapt.
- However, how much adaptation we will have to do depends on what we do to mitigate climate change.
  - There's a BIG difference between 2°C and 5°C.

Mitigation

- This is really a global issue; there's only so much we can do at a local scale.
- Forests represent a significant pool of carbon and have the potential to sequester and store even more.
  - Minimizing forest loss (deforestation)
  - Afforestation
  - More urban trees
  - Longer rotations
  - Improved stocking
  - Forest soils
- And use of woody biomass for energy can reduce emissions (if done correctly) and improve forest management (if done correctly).

Adaptation

- There are two types of adaptation:
  - Reactive adaptation is what people and systems do as impacts of climate change become apparent.
  - Proactive adaptation is when measures taken in advance to reduce potential risks of future climate change.
- Proactive adaptation is often more effective and less costly than reactive adaptation.
- Proactive adaptation is difficult, though, as it requires realistic projections of likely futures.

Proactive Adaptation

- We know that we can improve the adaptive capacity of our forests by improving forest health:
  - More urban trees
  - Maintain biodiversity
  - Ensure healthy regeneration rates
  - Overabundant deer
  - Acidic soils
  - Competing vegetation
  - Invasive species and diseases
  - Connectivity
- In other words, climate change just increases the urgency of doing what foresters have always done.
- But we may have to think differently
  - E.g., plantations, assisted migration

Questions?