

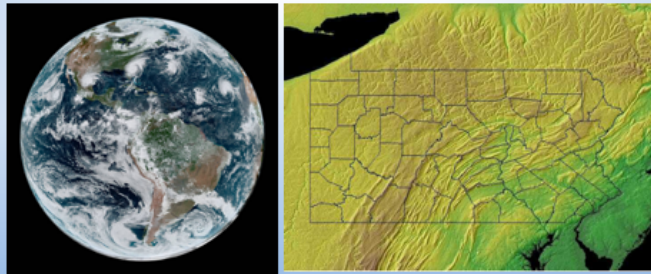
Regional Climate Change Impacts: What Science Tells Us

Raymond Najjar

The Pennsylvania State University

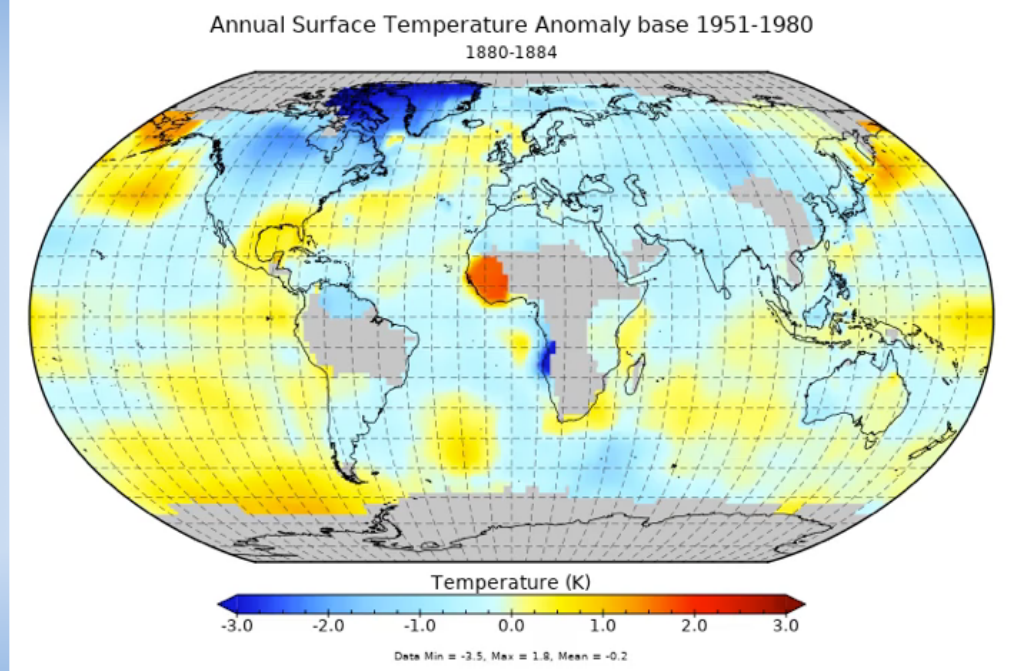
The p4 Pittsburgh Climate Action Summit

October 30, 2019



<https://www.nasa.gov/topics/earth/images/index.html>
Geology.com

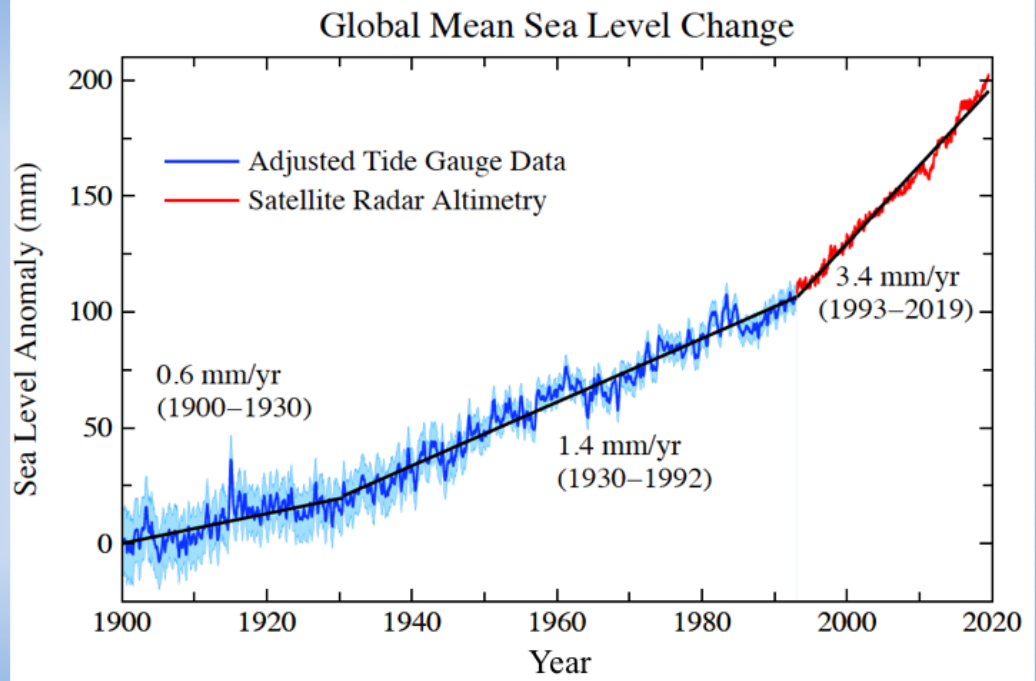
The world is warming almost everywhere



Source: NASA

<https://data.giss.nasa.gov/gistemp/animations/>

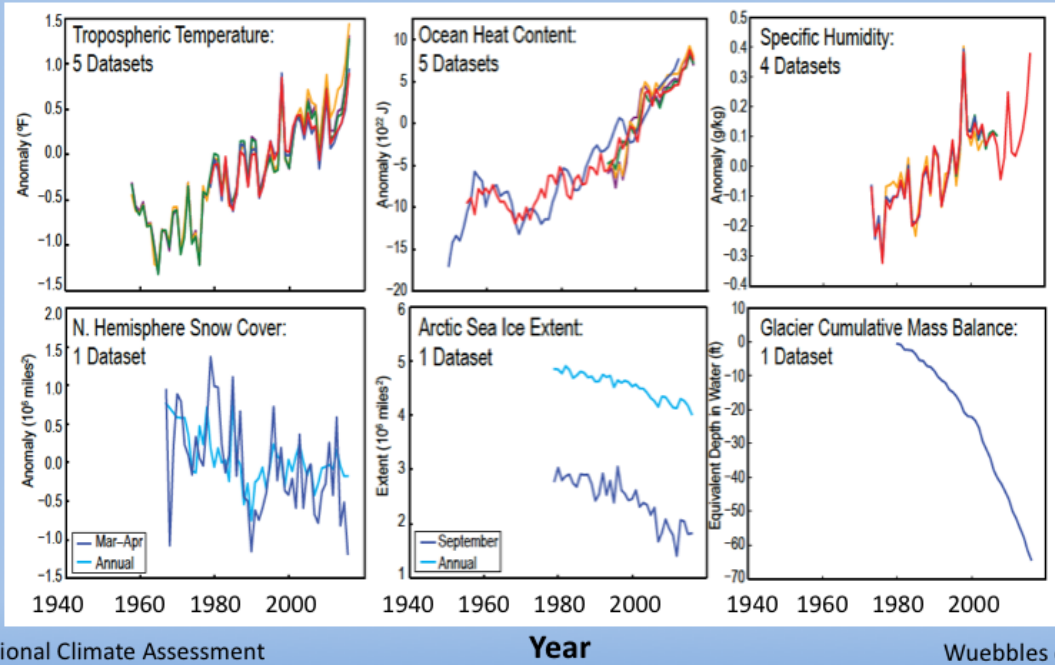
Sea level is accelerating



Columbia University Earth Institute

<http://www.columbia.edu/~mhs119/SeaLevel/>

Multiple lines of evidence of a warming world



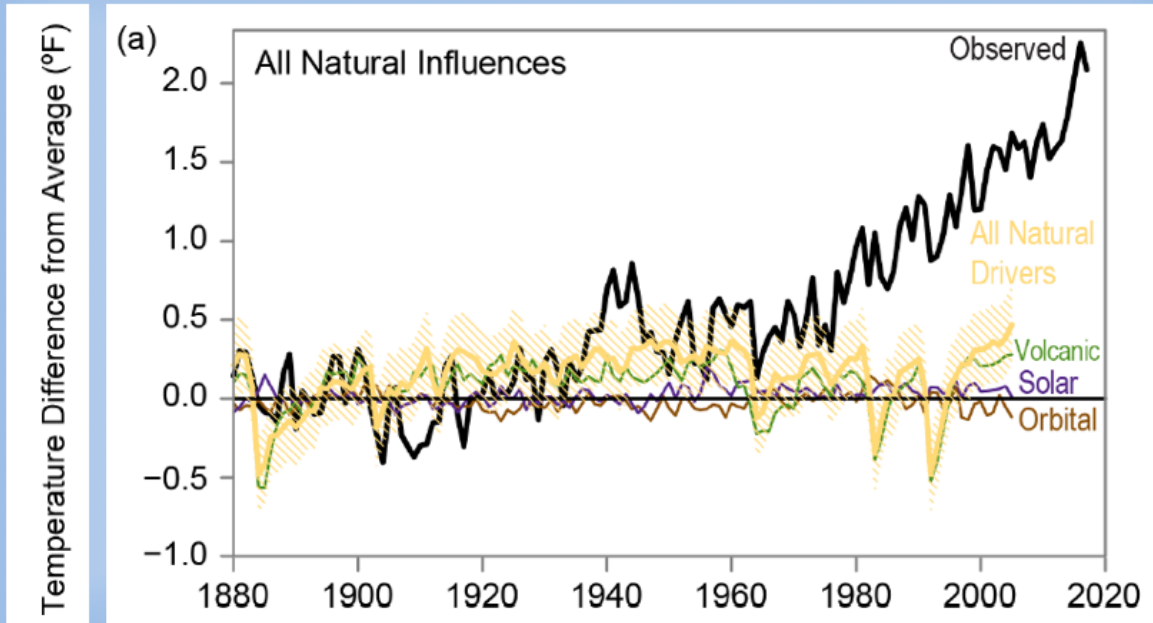
Fourth National Climate Assessment

Year

Wuebbles et al. (2017)

Wuebbles, D.J., Easterling, D.R., Hayhoe, K., Knutson, T., Kopp, R.E., Kossin, J.P., Kunkel, K.E., LeGrande, A.N., Mears, C., Sweet, W.V., Taylor, P.C., Vose, R.S., Wehner, M.F., 2017. Our globally changing climate. In: D.J. Wuebbles, D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, T.K. Maycock (Editors), Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program, Washington, DC, USA, pp. 35–72.

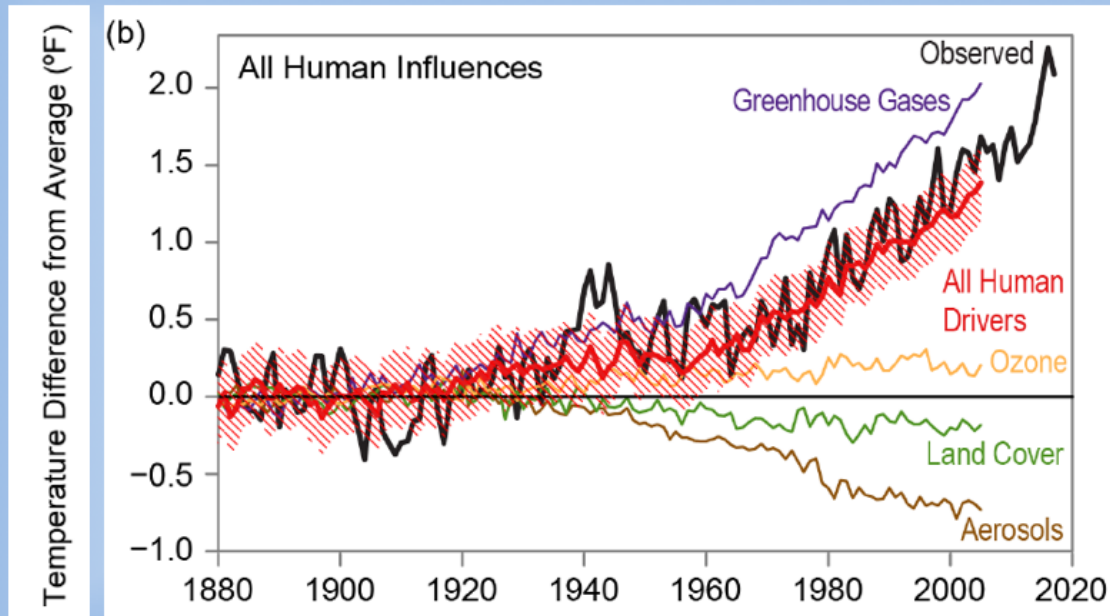
We cannot explain observed warming with natural drivers ...



Fourth National Climate Assessment, Hayhoe et al. (2018)

Hayhoe, K., Wuebbles, D.J., Easterling, D.R., Fahey, D.W., Doherty, S., Kossin, J., Sweet, W., Vose, R., Wehner, M., 2018. Our changing climate. In: D.R. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, B.C. Stewart (Editors), Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment. US Global Change Research Program, Washington, DC, USA, pp. 72–144.

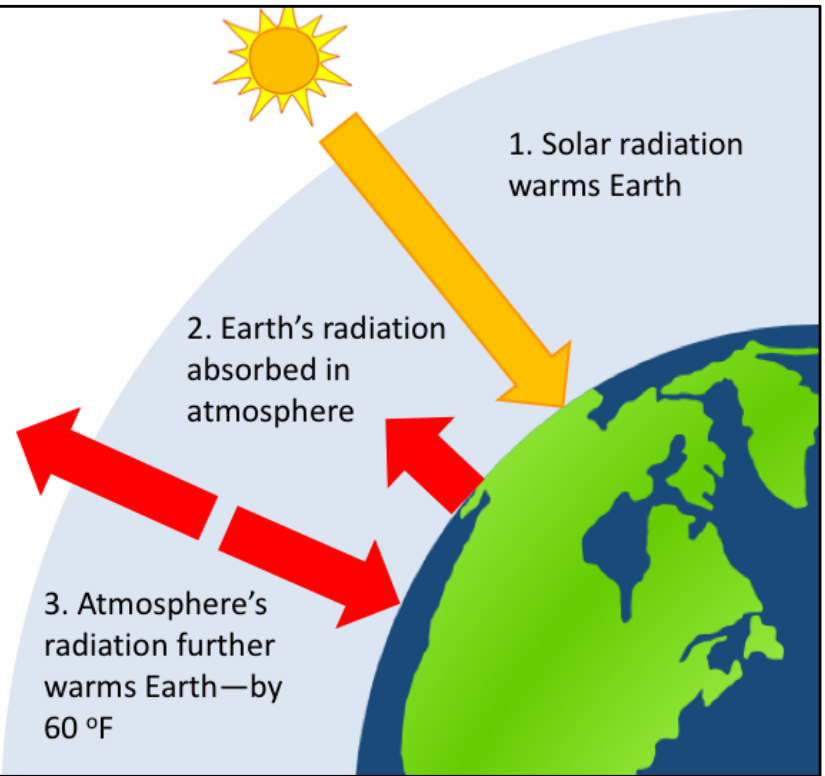
... but we can with human drivers



Fourth National Climate Assessment, Hayhoe et al. (2018)

Hayhoe, K., Wuebbles, D.J., Easterling, D.R., Fahey, D.W., Doherty, S., Kossin, J., Sweet, W., Vose, R., Wehner, M., 2018. Our changing climate. In: D.R. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, B.C. Stewart (Editors), Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment. US Global Change Research Program, Washington, DC, USA, pp. 72–144.

The
greenhouse
effect in three
steps



The greenhouse effect is well established

1824: Joseph Fourier describes natural greenhouse effect



1858–1861: Eunice Foote and John Tyndall identify greenhouse gases

1896: Svante Arrhenius estimates greenhouse effect of fossil fuel CO₂



1938: Guy Callendar documents warming and CO₂ increase

“Many lines of evidence demonstrate that it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century.”

“For the period extending over the last century, there are no convincing alternative explanations supported by the extent of the observational evidence.”

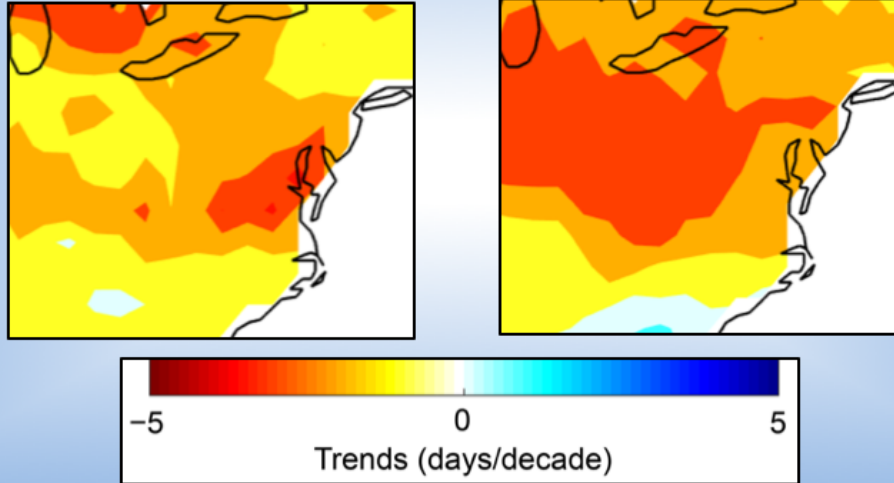
Fourth National Climate Assessment

Plants are leafing out and blooming earlier

1981–2010 trends of three indicator plants

First leaf

First bloom



Fourth National Climate Assessment, Lipton et al. (2018)

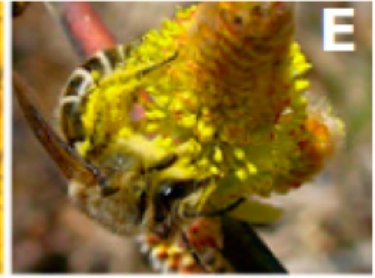
Lipton, D., M. A. Rubenstein, S.R. Weiskopf, S. Carter, J. Peterson, L. Crozier, M. Fogarty, S. Gaichas, K.J.W. Hyde, T.L. Morelli, J. Morissette, H. Moustahfid, R. Muñoz, R. Poudel, M.D. Staudinger, C. Stock, L. Thompson, R. Waples, and J.F. Weltzin, 2018: Ecosystems, Ecosystem Services, and Biodiversity. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 268–321. doi: 10.7930/NCA4.2018.CH7

Native bees in
Northeast US are
arriving in spring 10
days earlier than
they used to

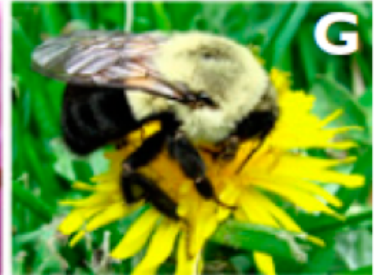
A. miserabilis



C. inaequalis



O. lignaria



B. impatiens

Bartomeus et al. (2011)

Bartomeus, I., Ascher, J.S., Wagner, D., Danforth, B.N., Colla, S., Kornbluth, S., Winfree, R., 2011. Climate-associated phenological advances in bee pollinators and bee-pollinated plants. *Proceedings of the National Academy of Sciences* 108, 20645-20649.

Birds in Western PA became smaller by 1.3% on average due to warming from 1961 to 2007



Scarlet tanager: 2% smaller



Rose-breasted grosbeak: 2% smaller

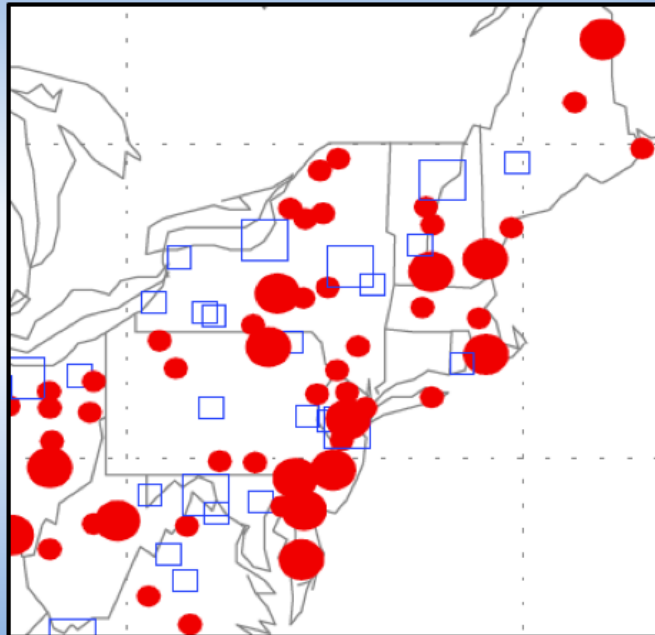
Van Buskirk et al. (2009, 2010)

Van Buskirk, J., Mulvihill, R.S., Leberman, R.C., 2010. Declining body sizes in North American birds associated with climate change. *Oikos* 119, 1047-1055.

Van Buskirk, J., Mulvihill, R.S., Leberman, R.C., 2009. Variable shifts in spring and autumn migration phenology in North American songbirds associated with climate change. *Global Change Biology* 15, 760-771.

The ratio of snow to total precipitation is mostly decreasing in the Northeast US

1949–2005 trend
● Decreasing
□ Increasing



Feng and Hu (2007)

Feng, S., Hu, Q., 2007. Changes in winter snowfall/precipitation ratio in the contiguous United States. *Journal of Geophysical Research: Atmospheres* 112, doi: 10.1029/2007jd008397.

With warming and snowpack reduction, Snowshoe Hare range in Pennsylvania has contracted



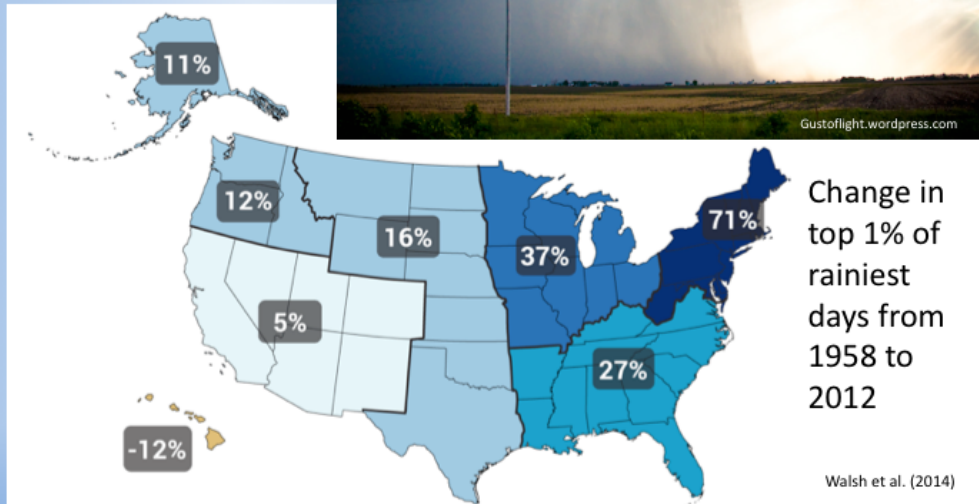
Diefenbach et al. (2016), Fourth National Climate Assessment (Lipton et al. 2018)

Diefenbach, D.R., Rathbun, S.L., Vreeland, J.K., Grove, D., Kanapaux, W.J., 2016. Evidence for range contraction of snowshoe hare in Pennsylvania. *Northeastern Naturalist* 23, 229-249.

Lipton, D., M. A. Rubenstein, S.R. Weiskopf, S. Carter, J. Peterson, L. Crozier, M. Fogarty, S. Gaichas, K.J.W. Hyde, T.L. Morelli, J. Morissette, H. Moustahfid, R. Muñoz, R. Poudel, M.D. Staudinger, C. Stock, L. Thompson, R. Waples, and J.F. Weltzin, 2018: Ecosystems, Ecosystem Services, and Biodiversity. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 268–321. doi: 10.7930/NCA4.2018.CH7

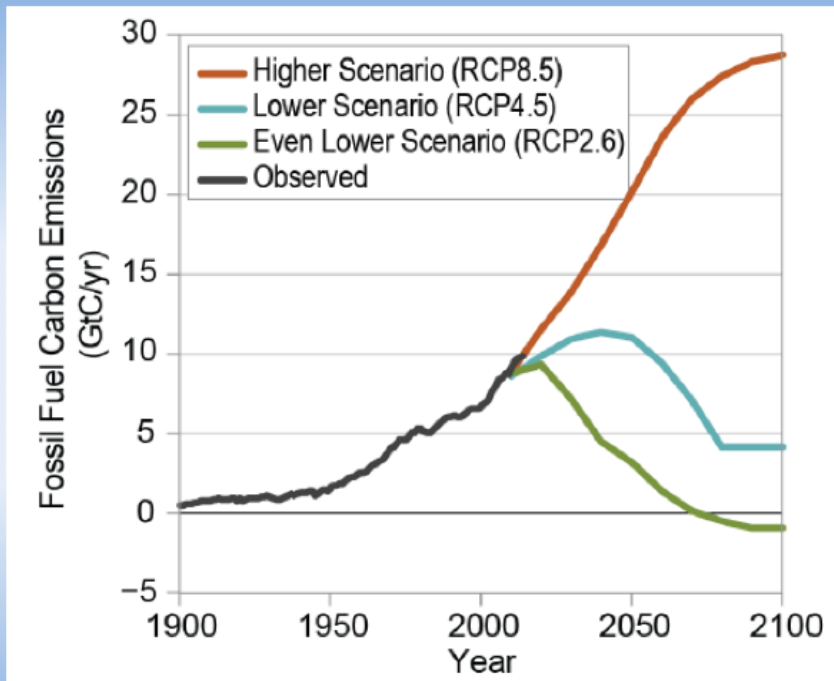
Photo credit: L. S. Mills research photo by Jaco and Lindsey Barnard, University of Montana Mills Research Lab.

Heavy precipitation is increasing



Walsh, J., Wuebbles, D., Hayhoe, K., Kossin, J., Kunkel, K., Stephens, G., Thorne, P., Vose, R., Wehner, M., Willis, J., Anderson, D., Doney, S., Feely, R., Hennon, P., Kharin, V., Knutson, T., Landerer, F., Lenton, T., Kennedy, J., Somerville, R., 2014. Chapter 2: Our Changing Climate. In: J.M. Melillo, T.C. Richmond, G.W. Yohe (Editors), Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, pp. 19-67.

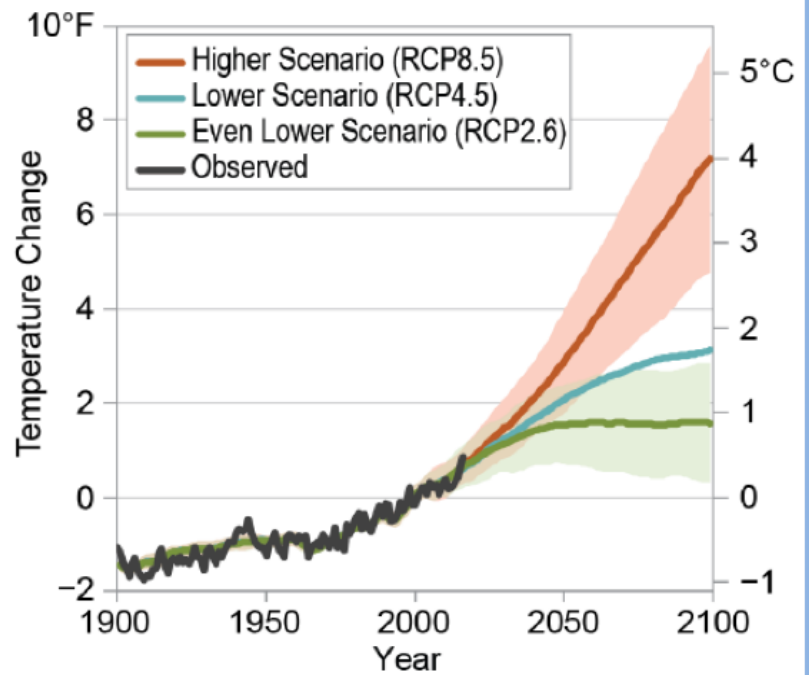
Three possible emissions futures ...



Fourth National Climate Assessment, Wuebbles et al. (2017)

Wuebbles, D.J., Easterling, D.R., Hayhoe, K., Knutson, T., Kopp, R.E., Kossin, J.P., Kunkel, K.E., LeGrande, A.N., Mears, C., Sweet, W.V., Taylor, P.C., Vose, R.S., Wehner, M.F., 2017. Our globally changing climate. In: D.J. Wuebbles, D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, T.K. Maycock (Editors), Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program, Washington, DC, USA, pp. 35–72.

... lead to
very different
climate
futures

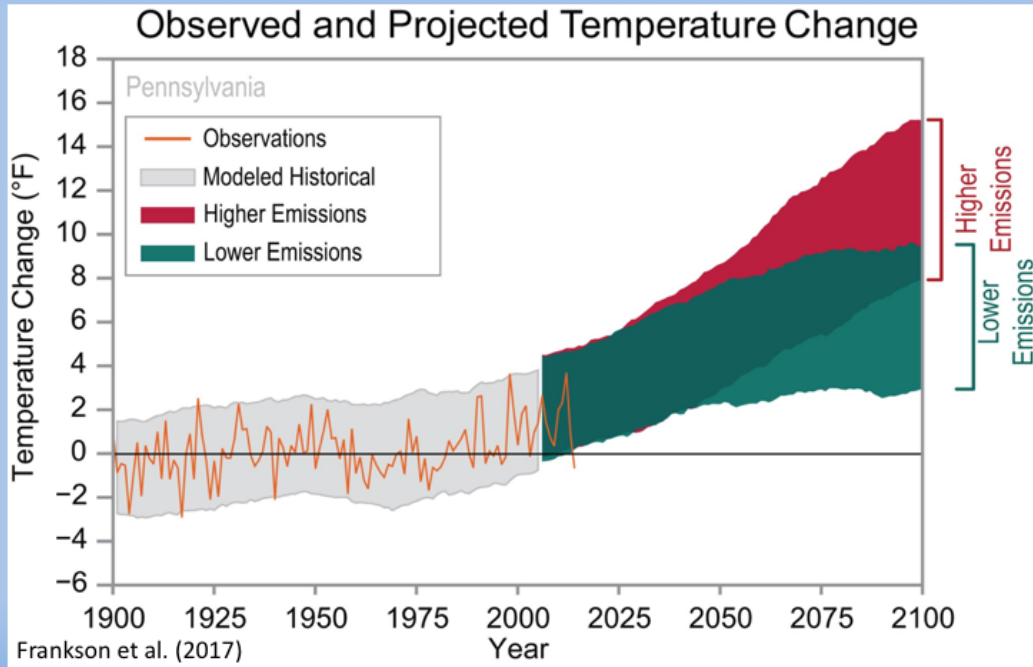


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Wuebbles, D.J., Easterling, D.R., Hayhoe, K., Knutson, T., Kopp, R.E., Kossin, J.P., Kunkel, K.E., LeGrande, A.N., Mears, C., Sweet, W.V., Taylor, P.C., Vose, R.S., Wehner, M.F., 2017. Our globally changing climate. In: D.J. Wuebbles, D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, T.K. Maycock (Editors), Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program, Washington, DC, USA, pp. 35–72.

Pennsylvania is following the global trend

Observed and Projected Temperature Change

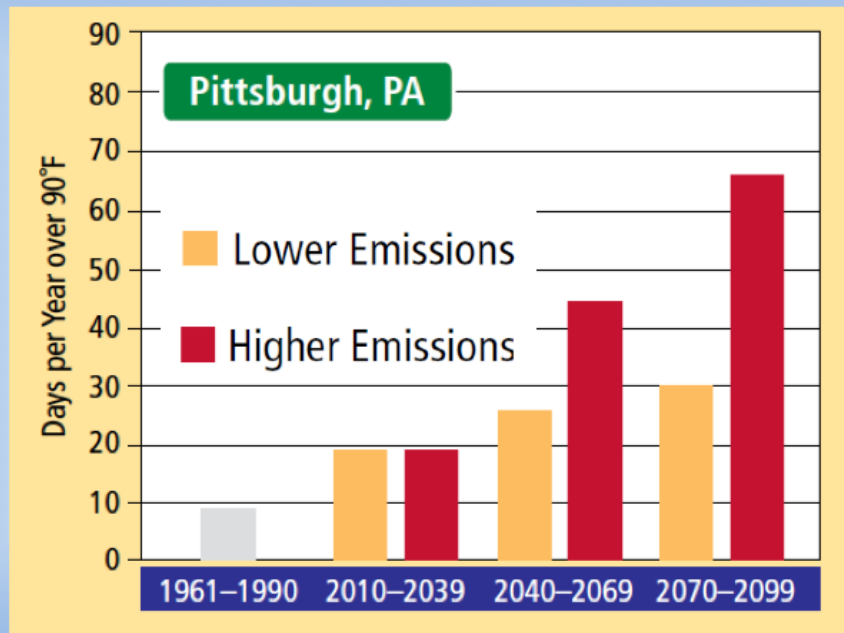


Frankson, R., Kunkel, K., Champion, S., Stewart, B., DeGaetano, A.T., Sweet, W., 2017. Pennsylvania State Climate Summary. NOAA Technical Report NESDIS 149-PA, 4 pp.



Summers in Pennsylvania will feel like those of the Southeast US by mid-century if heat trapping emissions trends continue

Emissions really matter, especially in the long run

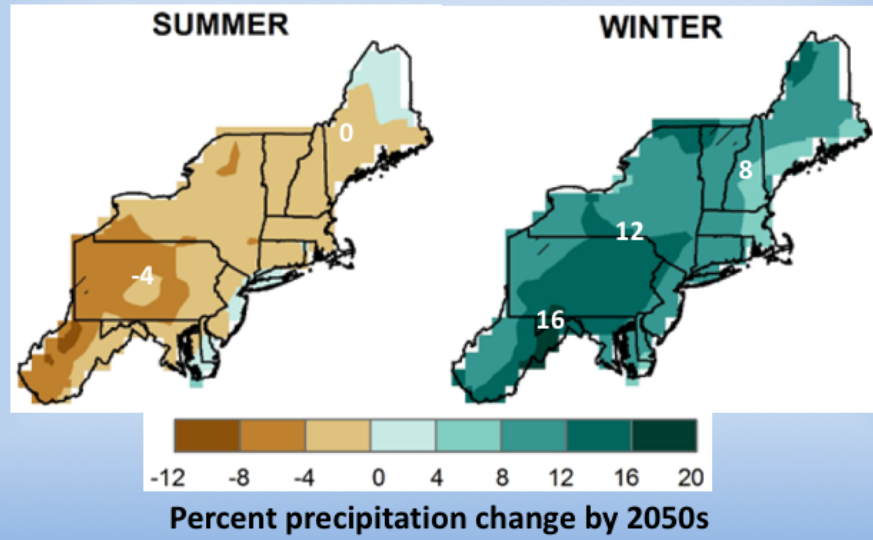


Union of Concerned Scientists (2008)

Union of Concerned Scientists, 2008. Climate Change in Pennsylvania: Impacts and Solutions for the Keystone State. Cambridge, MA, 54 pp.

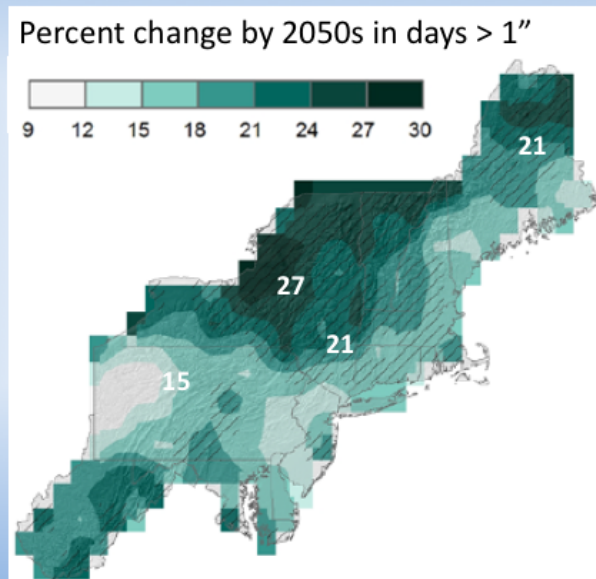
**Expect summers to
be drier ...**

**... and winters to
be wetter**



Kunkel et al. (2013)

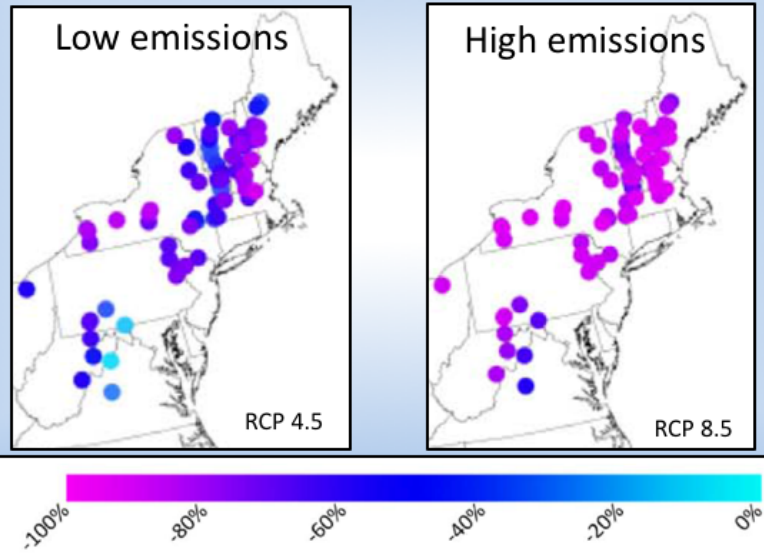
Expect heavy downpours to continue to increase



Kunkel et al. (2013)

Kunkel, K.E., Stevens, L.E., Stevens, S.E., Sun, L., Janssen, E., Wuebbles, D., Rennells, J., DeGaetano, A., Dobson, J.G., 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Part 1. Climate of the Northeast U.S., NOAA Technical Report NESDIS 142-1. U.S. Department of Commerce, Washington, D.C., 79 pp.

Projected change in downhill skiing season length by 2090



Wobus et al. (2017)

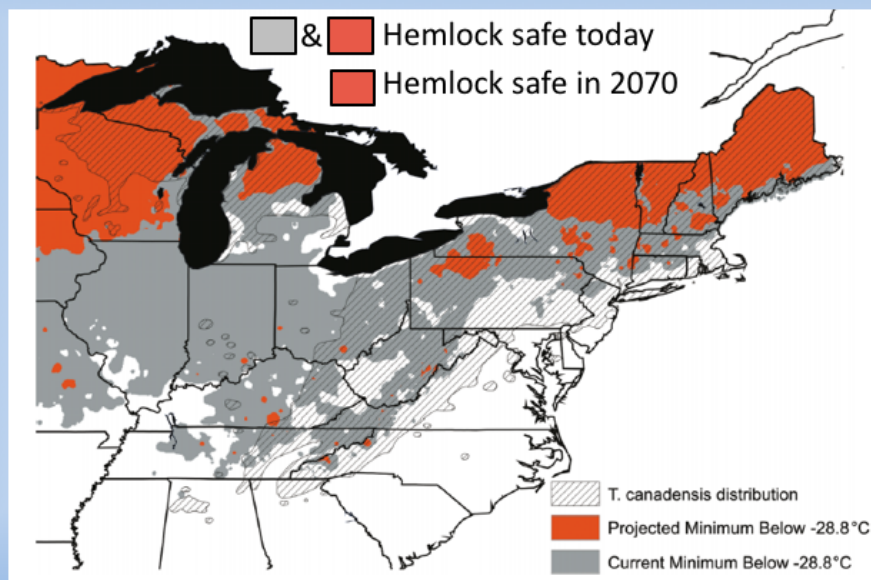
Wobus, C., Small, E.E., Hosterman, H., Mills, D., Stein, J., Rissing, M., Jones, R., Duckworth, M., Hall, R., Kolian, M., 2017. Projected climate change impacts on skiing and snowmobiling: A case study of the United States. *Global environmental change* 45, 1-14.

The woolly adelgid harms the Eastern Hemlock tree (PA state tree)



savingshemlocks.org

Warming winters allow the woolly adelgid to do more damage



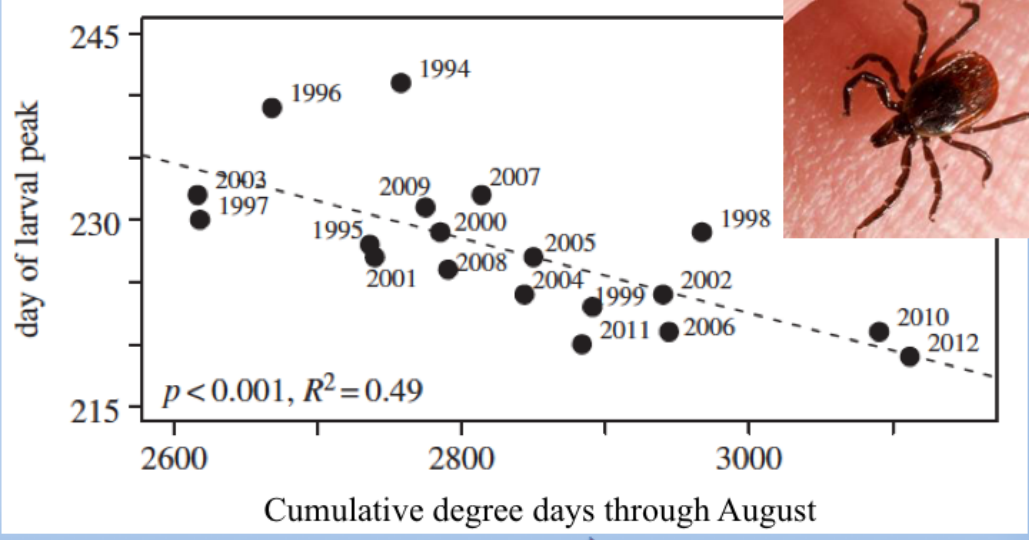
Dukes et al. (2009) A2 scenario, 2070, average of nine GCMs

Dukes, J.S., Pontius, J., Orwig, D., Garnas, J.R., Rodgers, V.L., Brazee, N., Cooke, B., Theoharides, K.A., Stange, E.E., Harrington, R., 2009. Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: What can we predict? *Canadian Journal of Forest Research* 39, 231-248.

In Millbrook, NY, warming has led to an earlier larval peak of the blacklegged (deer) tick, the major Lyme disease transmitter



Earlier larval peak



Warmer years

Levi et al. (2015)

Levi, T., Keesing, F., Oggenfuss, K., Ostfeld, R.S., 2015. Accelerated phenology of blacklegged ticks under climate warming. Philosophical Transactions of the Royal Society B: Biological Sciences 370, 20130556.

We have cleaned up
our own messes before

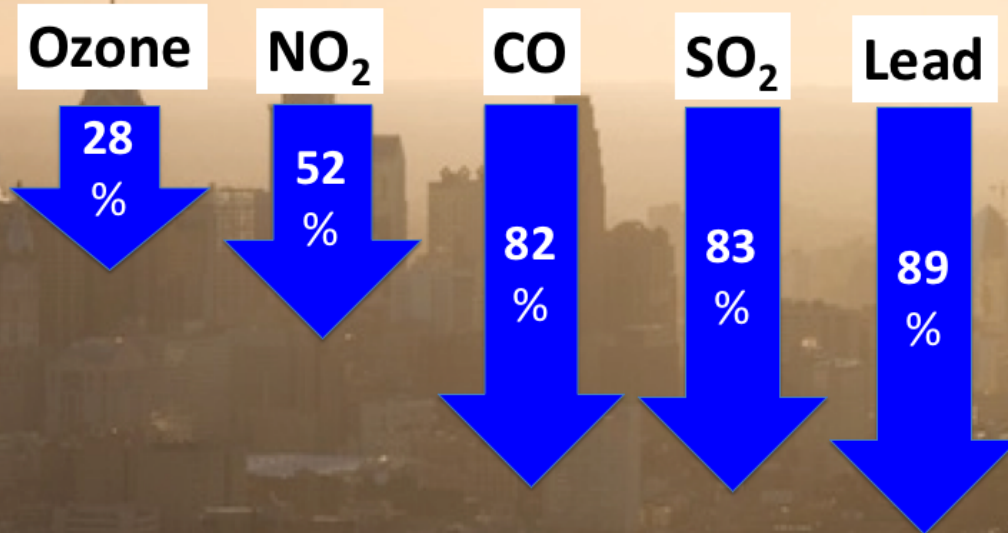
“Smog episodes”

October 1948: Pollution from zinc mills in Donora, PA combined with a temperature inversion, leads to 20 deaths



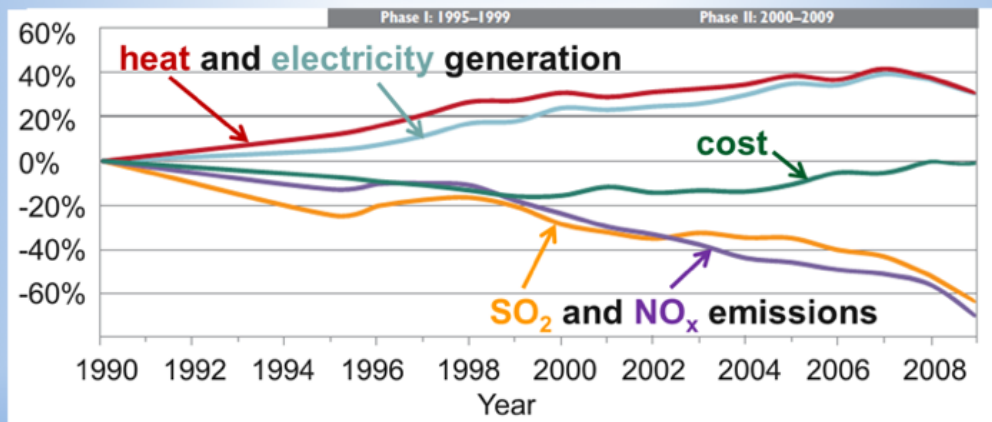
Source: Donora Smog Museum

This is happening much less often than it used to because ...



Median change in US: 1980-2010 Data source: www3.epa.gov/airtrends

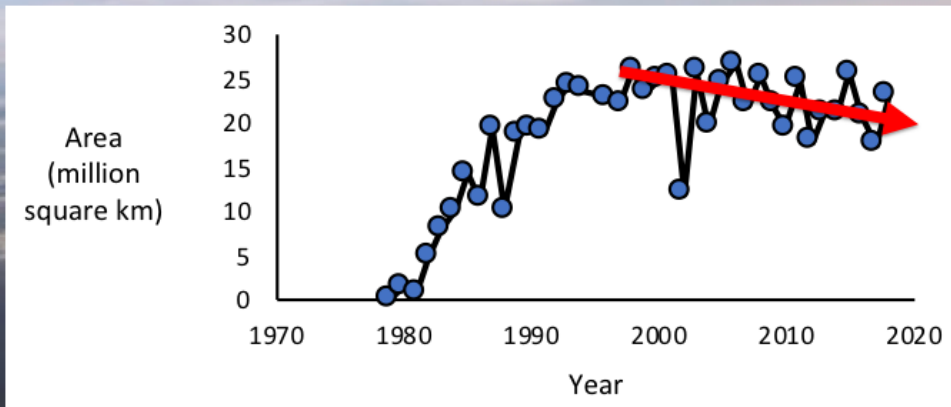
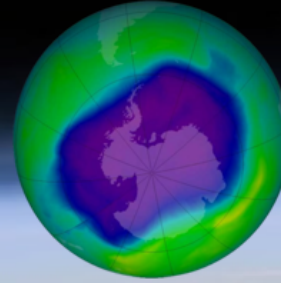
The Clean Air act reduced emissions and created \$170 - \$430 billion per year in health benefits—all while energy use went up and costs went down!



Burns et al. (2011)

Burns, D.A., Baron, J.S., Cosby, B.J., Fenn, M.E., Lynch, J.A., 2011. National Acid Precipitation Assessment Program Report to Congress 2011: An Integrated Assessment. National Science and Technology Council, United States Government, Washington, D.C., 114 pp.

Good news: the ozone hole is shrinking!



NASA

NASA image

https://ozonewatch.gsfc.nasa.gov/statistics/annual_data.html

Take-home messages

1. Pennsylvania has followed the global warming trend
2. Impacts are already being felt in multiple ways
3. Human-induced climate change will continue to occur regardless of emissions scenario; further adaptation is necessary.
4. The climate of the mid century and beyond is very sensitive to the emissions scenario.
5. Good science and good policy has gotten us out of environmental messes before

References

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