The oceans and climate change

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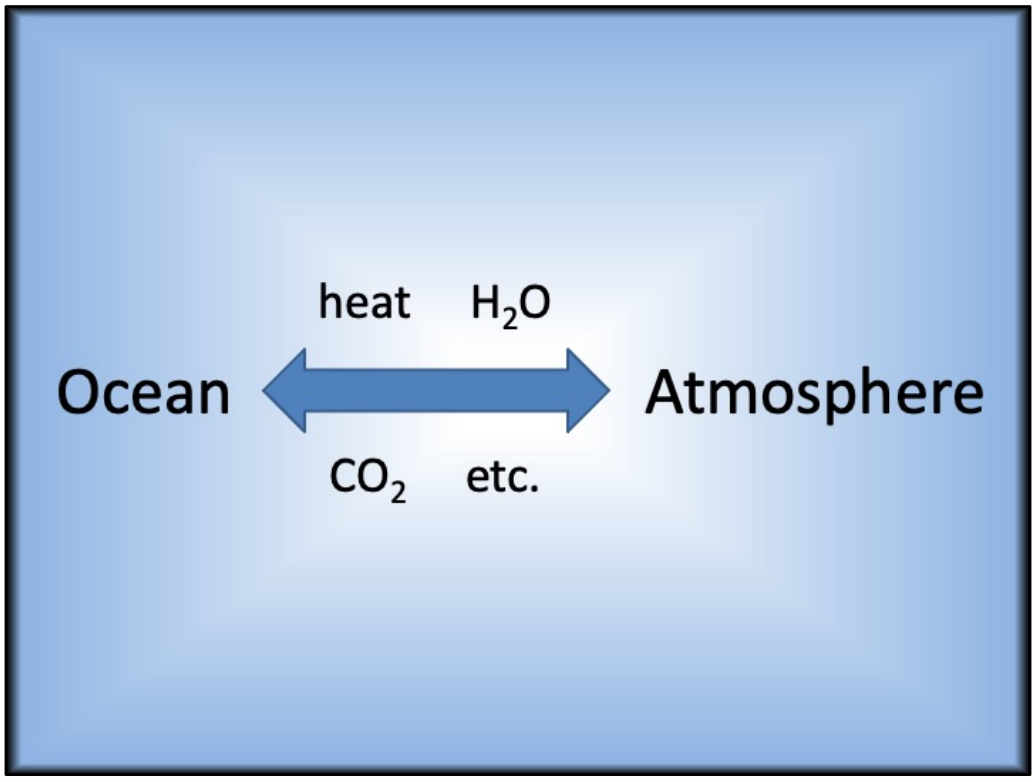
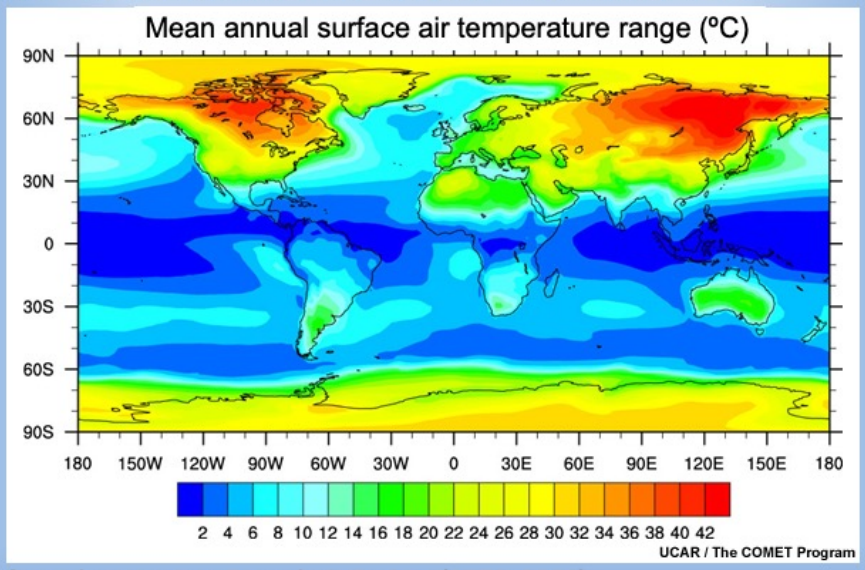
Outline

- The ocean's role in the climate system
- Impacts of anthropogenic CO_2 emissions on the ocean
- Future climate scenarios
- Solutions
- Past environmental successes
- What you can do

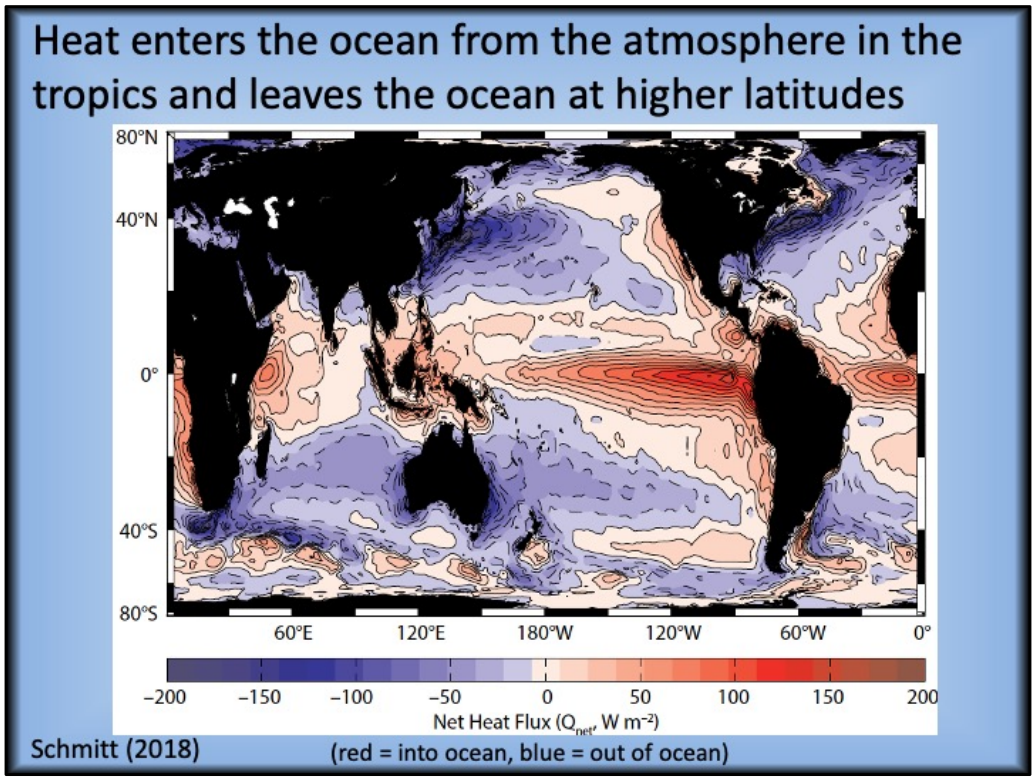
The ocean's role in the climate system


heat
H_2O
Ocean
Atmosphere
CO_2
etc.

The seasonal temperature *range* (temperature of warmest month minus temperature of coldest month) is much smaller over the ocean than over land

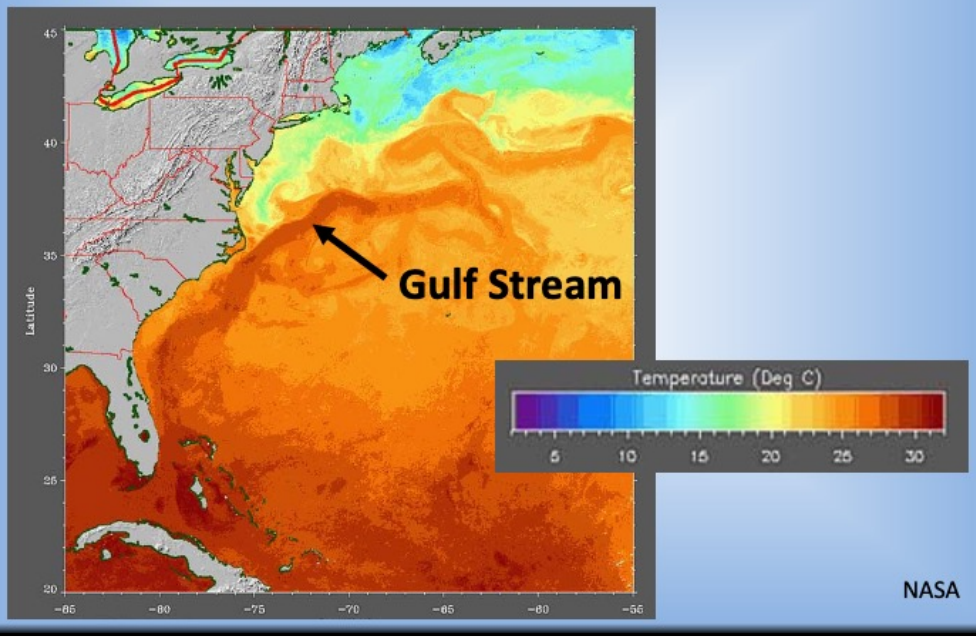


Data from the Japanese Reanalysis Project (1979–2004)



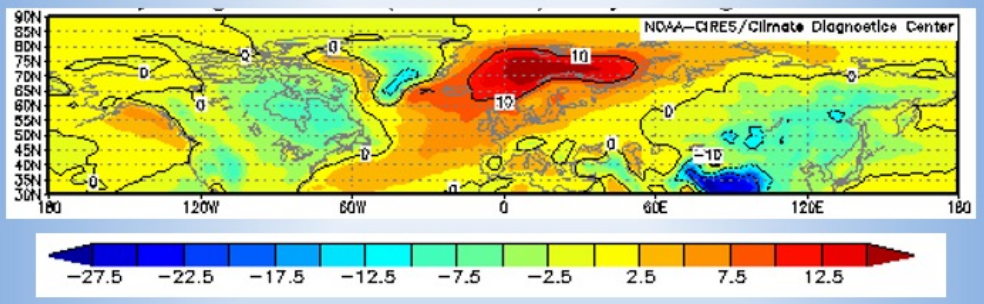
Schmitt, R.W. 2018. The ocean's role in climate. Oceanography 31(2):32–40, https://doi.org/10.5670/oceanog.2018.225 .

The Gulf Stream has a large impact on surface temperature

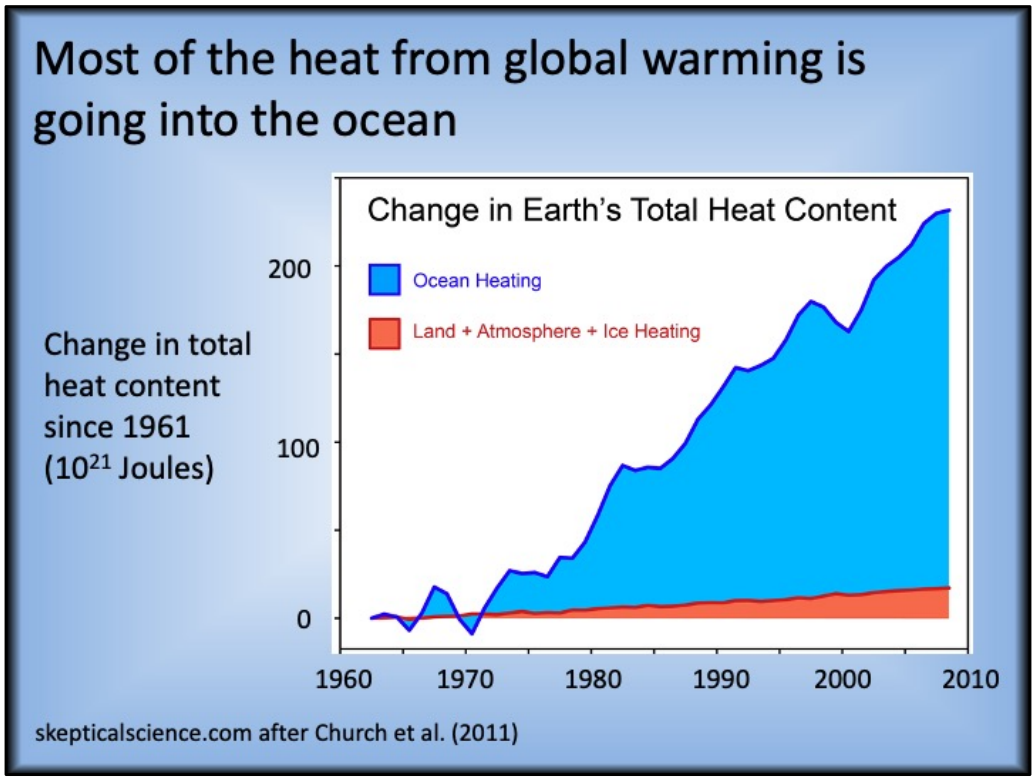


The Gulf Stream keeps Northern Europe relatively warm

Departure of air temperature from its longitudinal (east–west) average (°C)



1968–1996 average. From the NCEP reanalysis atlas.



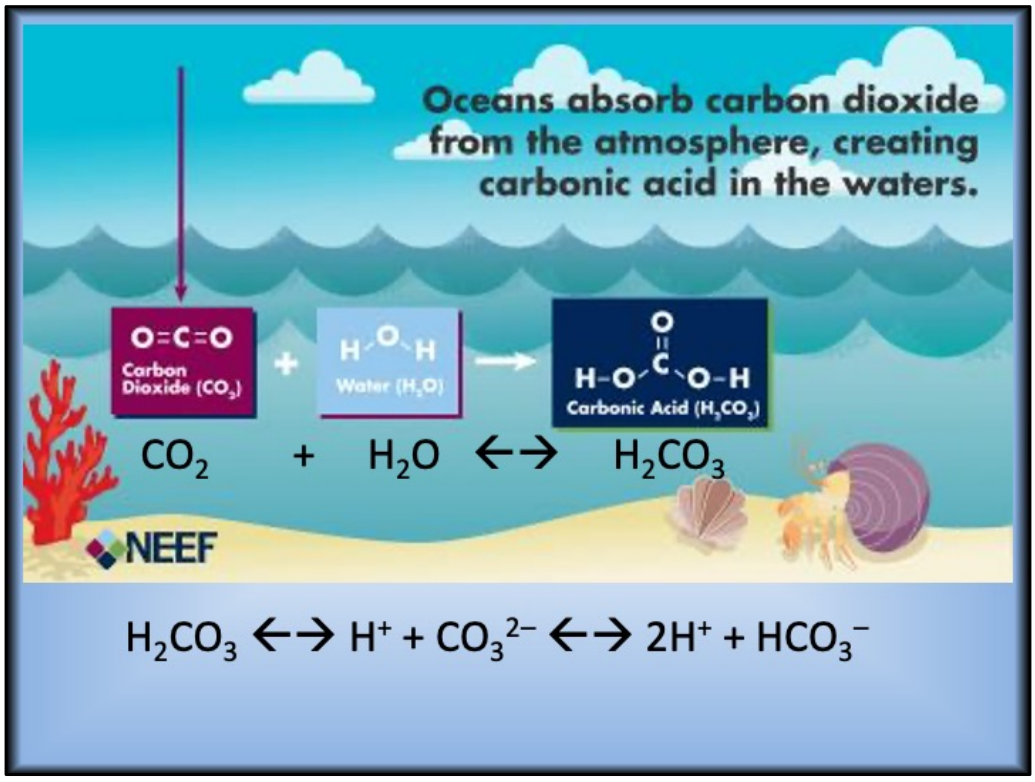
Church, J.A., White, N.J., Konikow, L.F., Domingues, C.M., Cogley, J.G., Rignot, E., Gregory, J.M., van den Broeke, M.R., Monaghan, A.J., Velicogna, I., 2011. Revisiting the Earth's sea-level and energy budgets from 1961 to 2008. Geophysical Research Letters 38, L18601.

The ocean is the largest reservoir of carbon on Earth that readily exchanges with the atmosphere

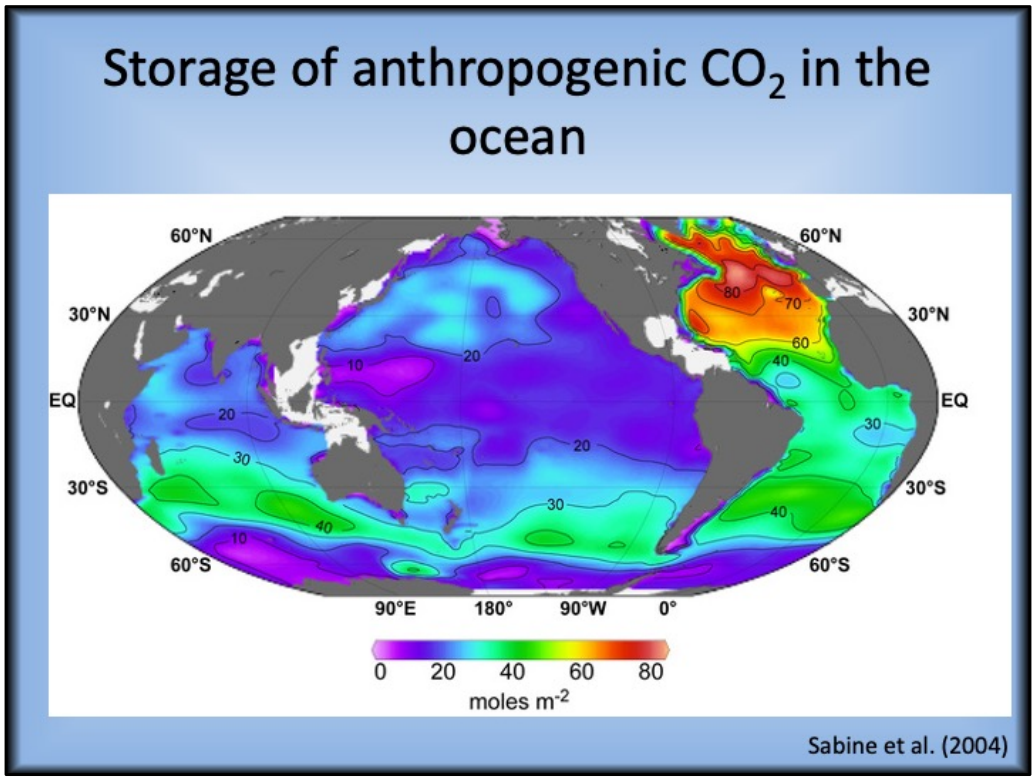
Reservoir	Size, Gigatons Carbon (IPCC)
Ocean	38,100 GtC
Soils and Vegetation	2,410 GtC
Atmosphere	760 GtC
Ocean Sediments	1,750 GtC
Permafrost	1,700 GtC
Fossil Fuel Reserves	1,940 GtC (max. est.)

Schmitt (2018)

Schmitt, R.W. 2018. The ocean's role in climate. Oceanography 31(2):32–40, https://doi.org/10.5670/oceanog.2018.225 .



$H_2CO_3 \leftrightarrow H^+ + CO_3^{2-} \leftrightarrow 2H^+ + HCO_3^-$



Sabine, C.L., Feely, R.A., Gruber, N., Key, R.M., Lee, K., Bullister, J.L., Wanninkhof, R., Wong, C., Wallace, D.W., Tilbrook, B., 2004. The oceanic sink for anthropogenic CO_2. Science 305, 367-371.

GLOBAL CARBON PROJECT

Global carbon budget (2009–2018)

Sources = **Sinks**

34.7 $GtCO_2$/yr

86%

14%

5.5 $GtCO_2$/yr

17.9 $GtCO_2$/yr

44%

29%

11.5 $GtCO_2$/yr

23%

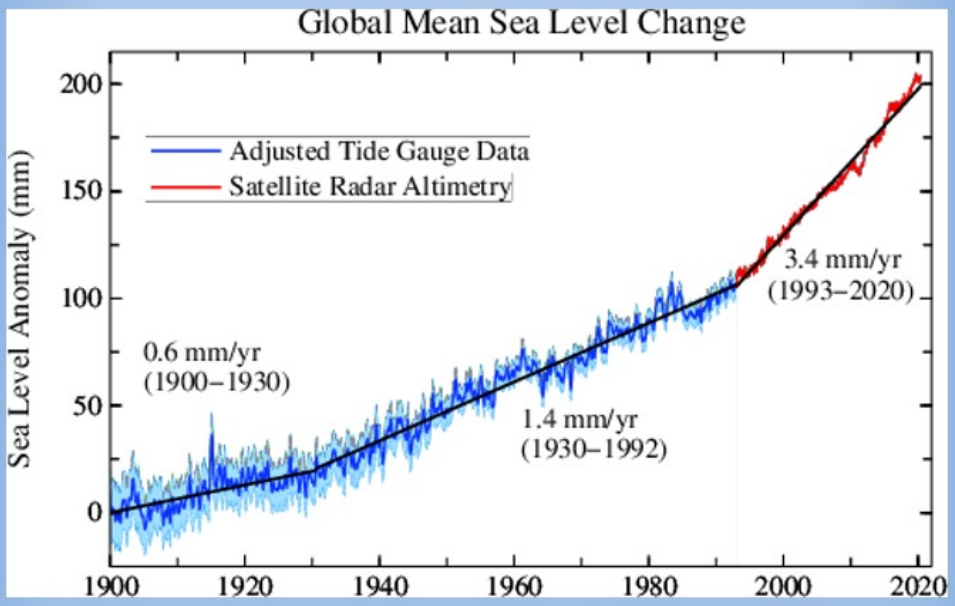
9.2 $GtCO_2$/yr

Budget Imbalance:
(the difference between estimated sources & sinks)

4%
1.6 $GtCO_2$/yr

Impacts of anthropogenic CO_2 emissions on the ocean

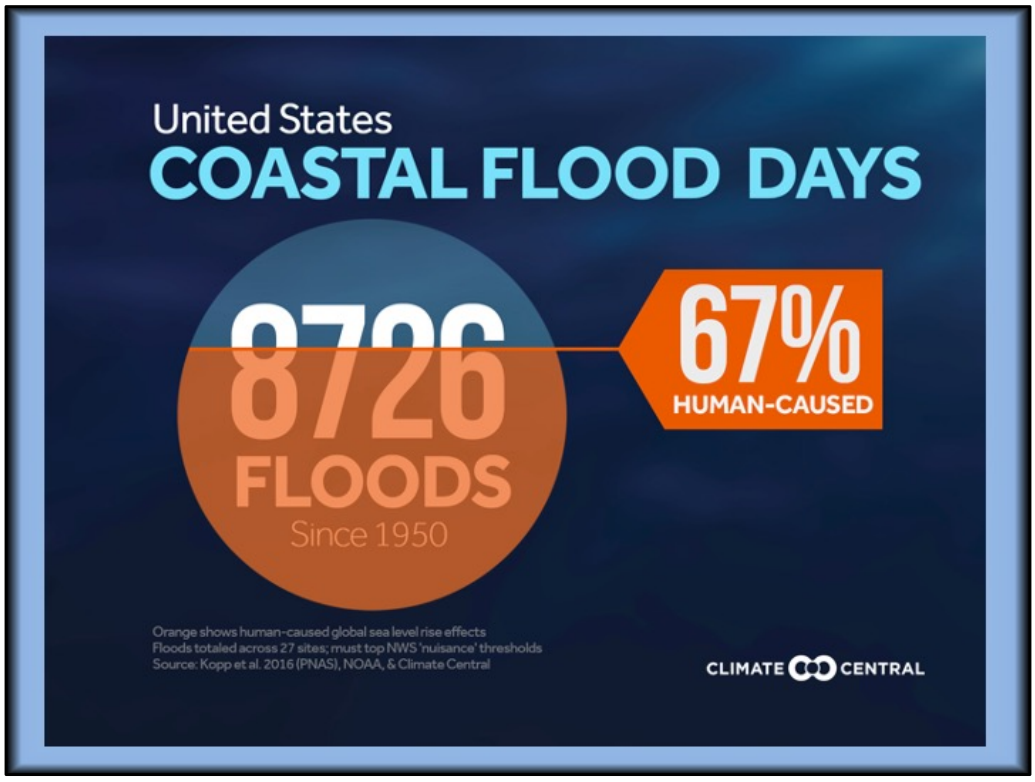
Sea level is accelerating



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

“Sunny day” flooding in Miami

Photo source: Grist


United States
COASTAL FLOOD DAYS
8726
FLOODS
Since 1950
67%
HUMAN-CAUSED
Orange shows human-caused global sea level rise effects
Floods totaled across 27 sites; must top NWS 'nuisance' thresholds
Source: Kopp et al. 2016 (PNAS), NOAA, & Climate Central
CLIMATE CENTRAL

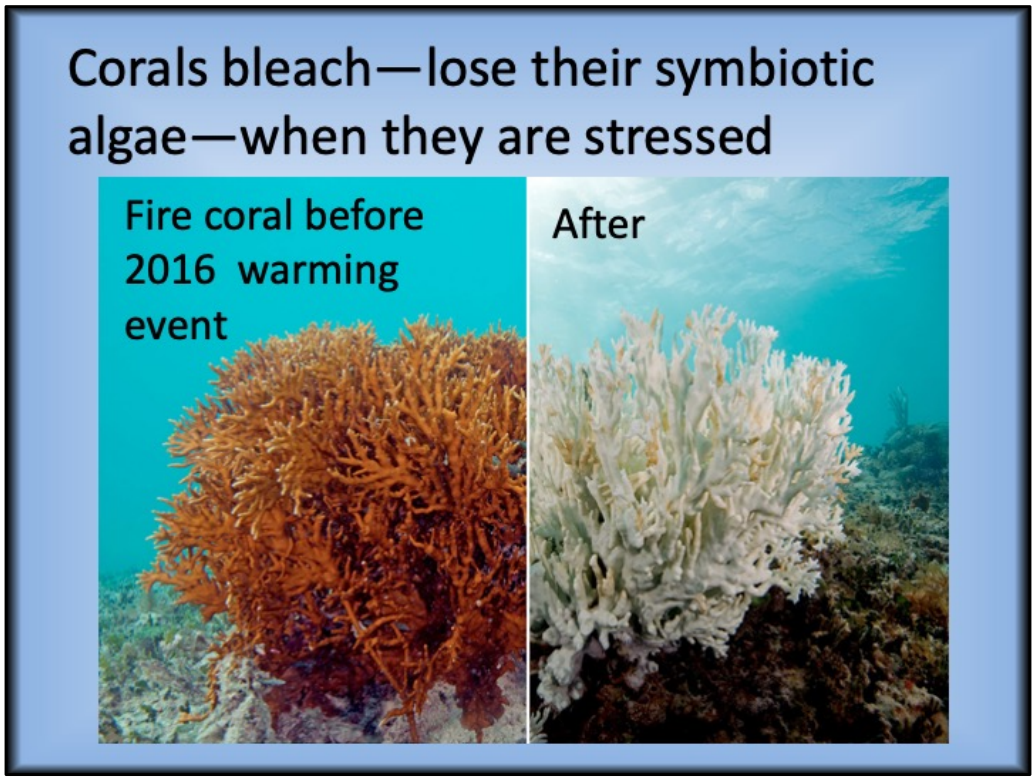
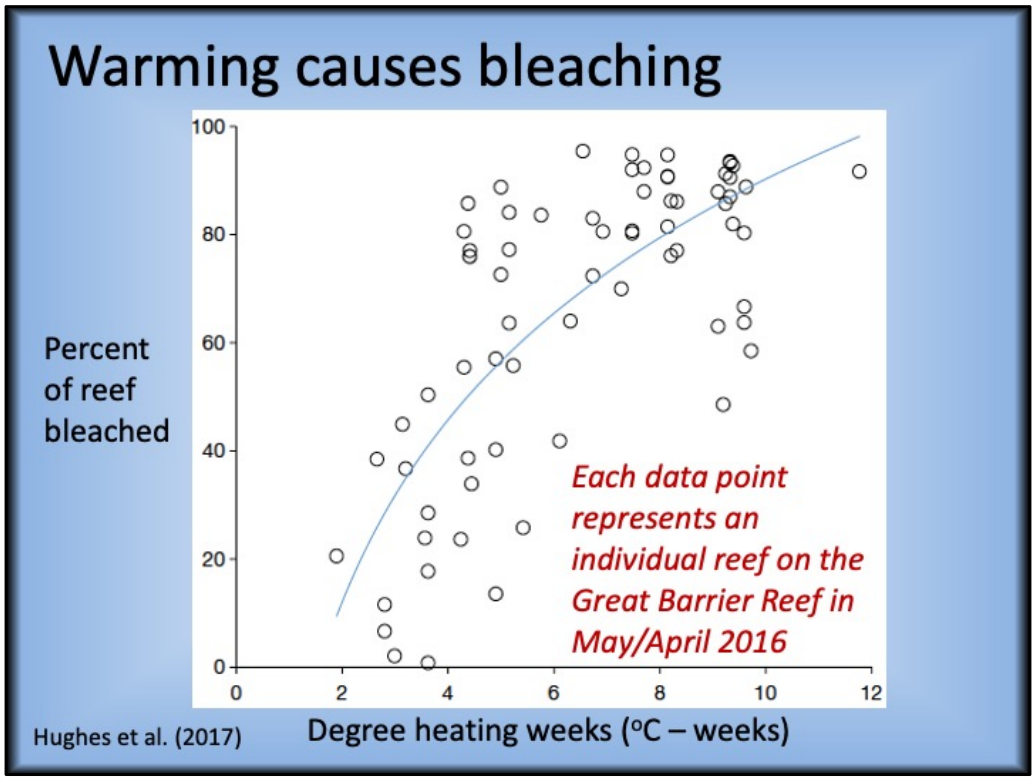


Photo of a fire coral that experienced severe bleaching in the 2016 mass bleaching event. The Ocean Agency / XL Catlin Seaview Survey / Richard Vevers. https://www.vox.com/science-and-health/2017/4/18/15272634/catastrophic-coral-bleaching-great-barrier-reef-map



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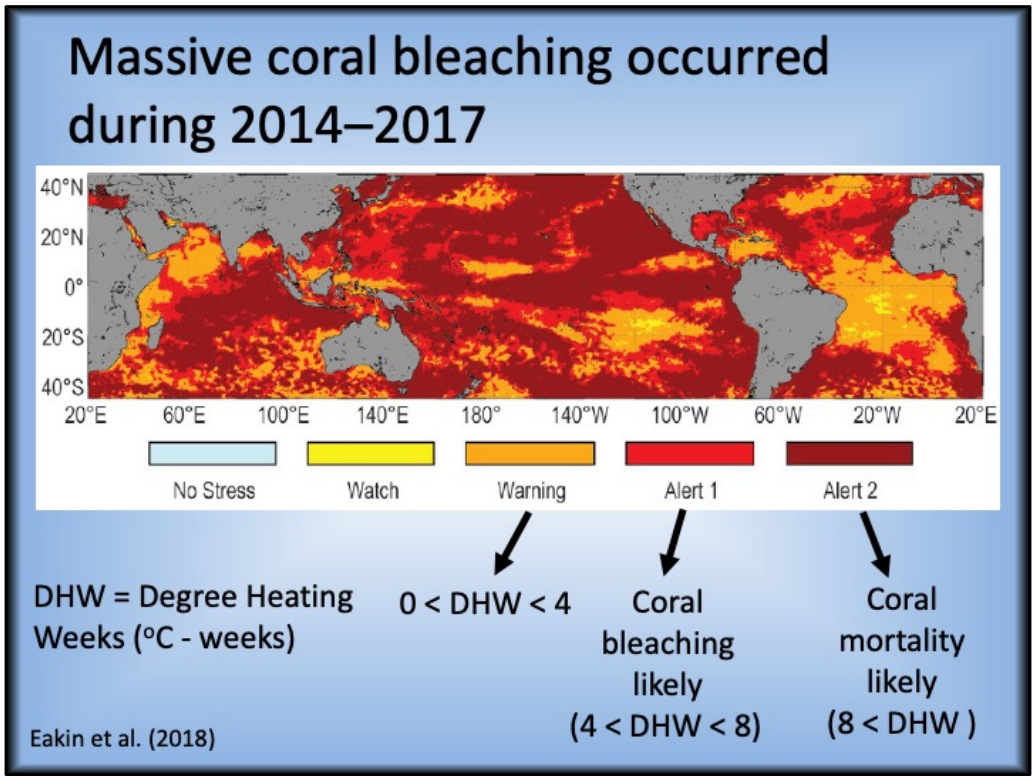
Degree heating weeks are a bit complicated. First you compute the mean annual cycle in SST at monthly resolution. Second, of these 12 months, you find the month with the highest mean SST and you call it the maximum monthly mean (MMM) SST. The bleaching threshold is 1 deg C above the MMM. Third, you look at the past 12 weeks and find all of the half-week periods in which the 50-km SST is above the threshold. Call the exceedance DT. For each half week period, you multiply DT by 0.5 weeks. Then you add up all of these products to get DHW. Source: https://coralreefwatch.noaa.gov/satellite/education/tutorial/crw24_dhw_product.php



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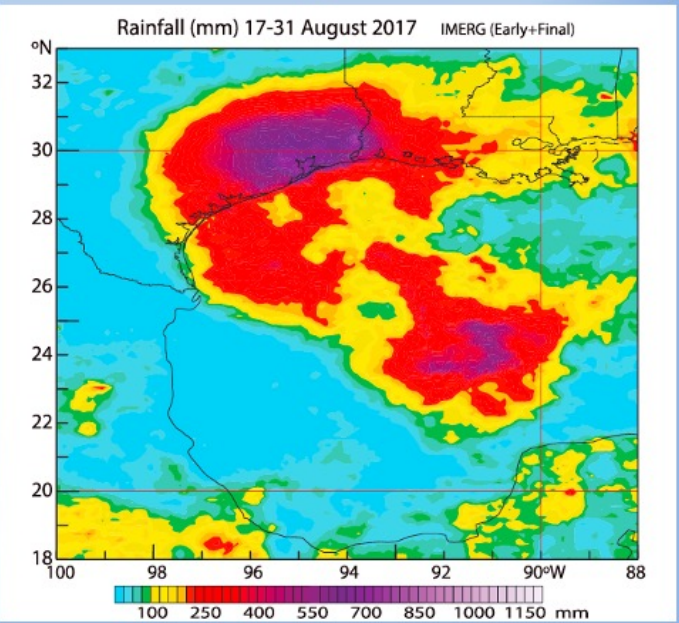
Record high ocean temperatures intensified Harvey and increased its flooding rains on land

"Harvey could not have produced so much rain without human-induced climate change"

Trenberth et al. (2018)



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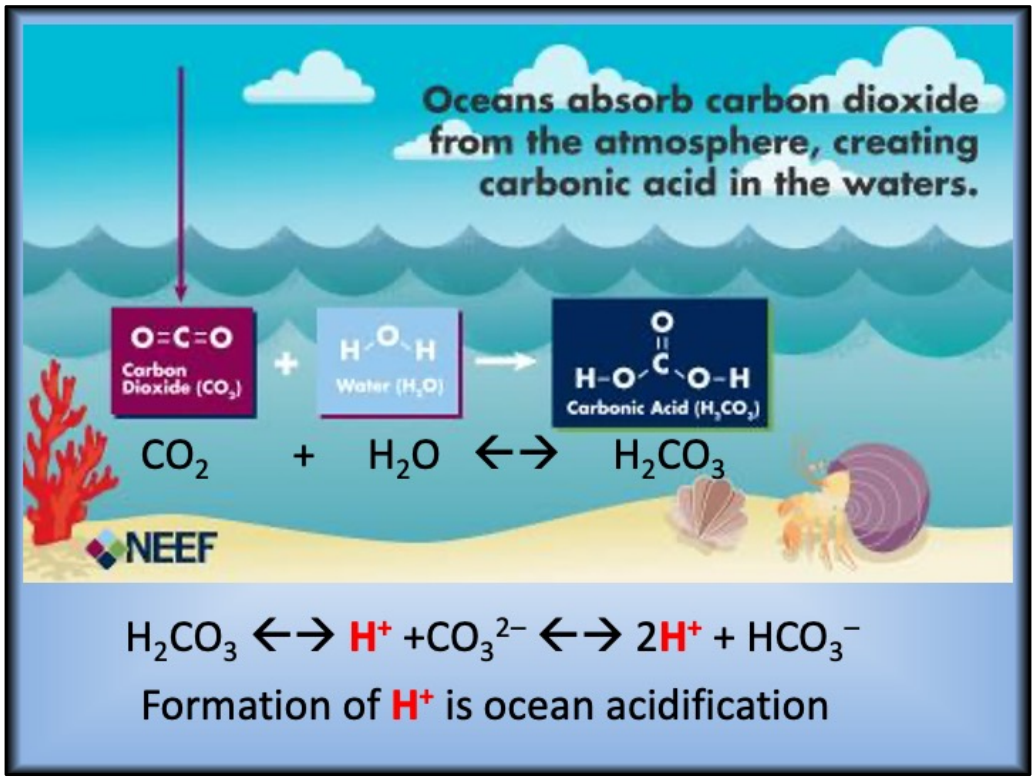
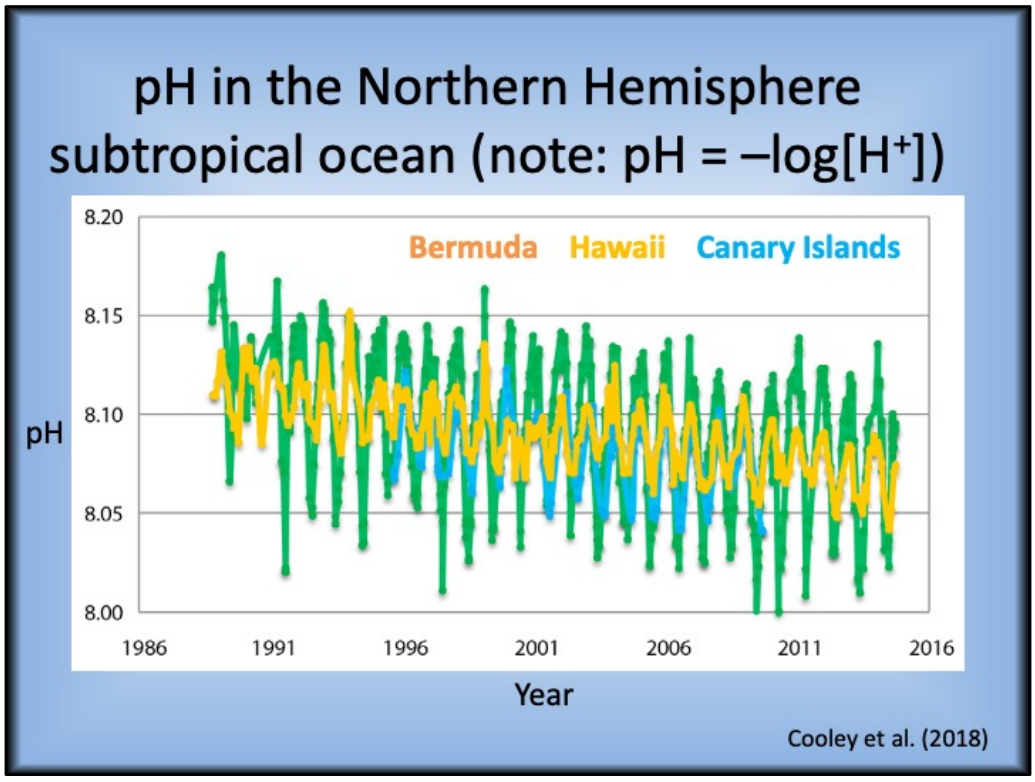


H_2CO_3 ←→ H^+ + CO_3^{2-} ←→ 2H^+ + HCO_3^-

Formation of H^+ is ocean acidification



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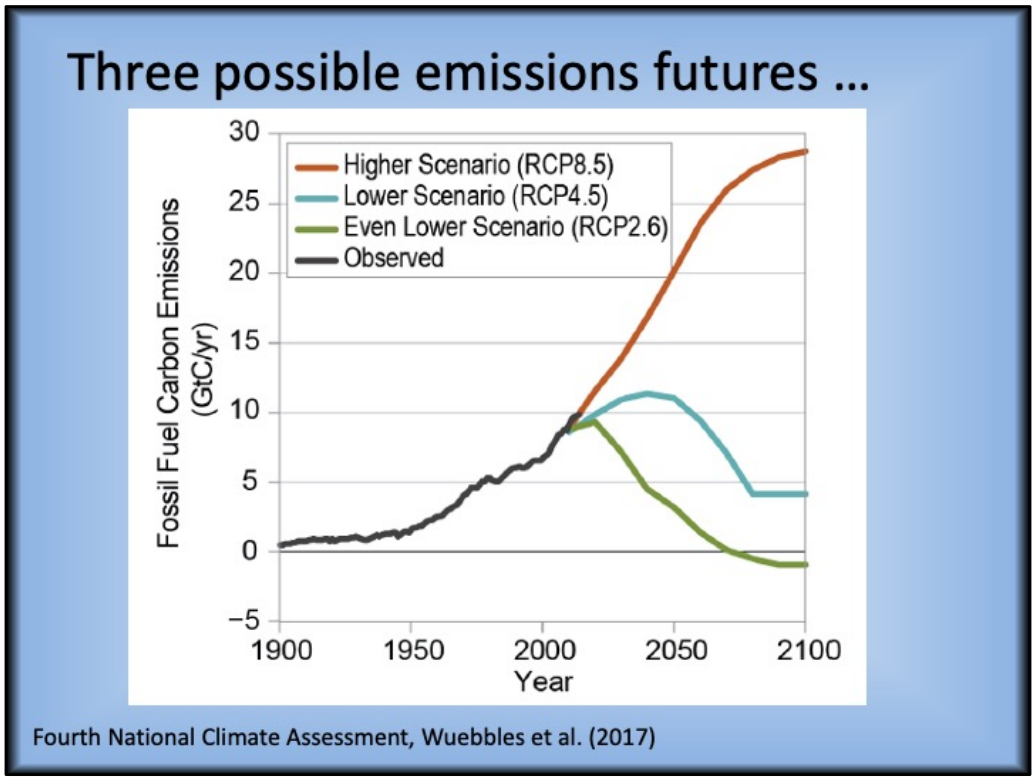
Future climate scenarios



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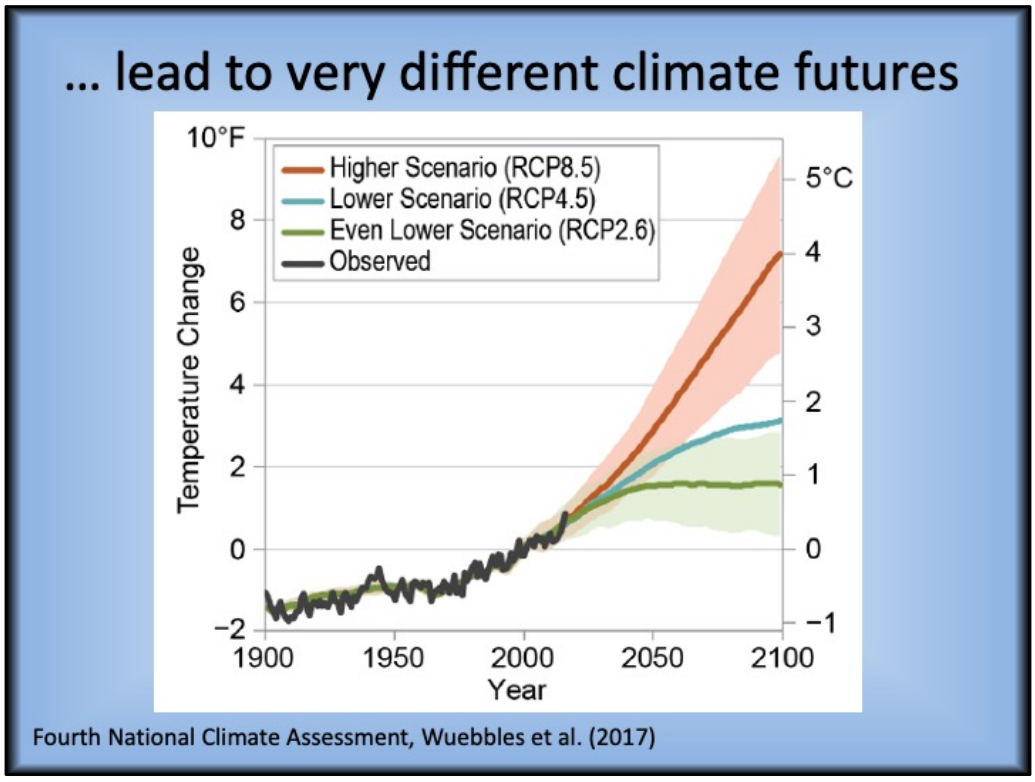

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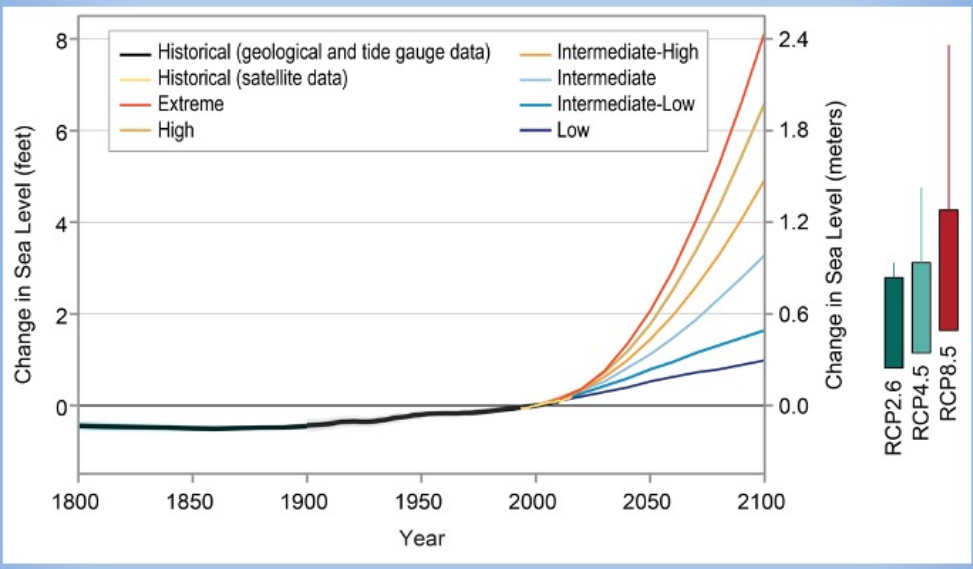
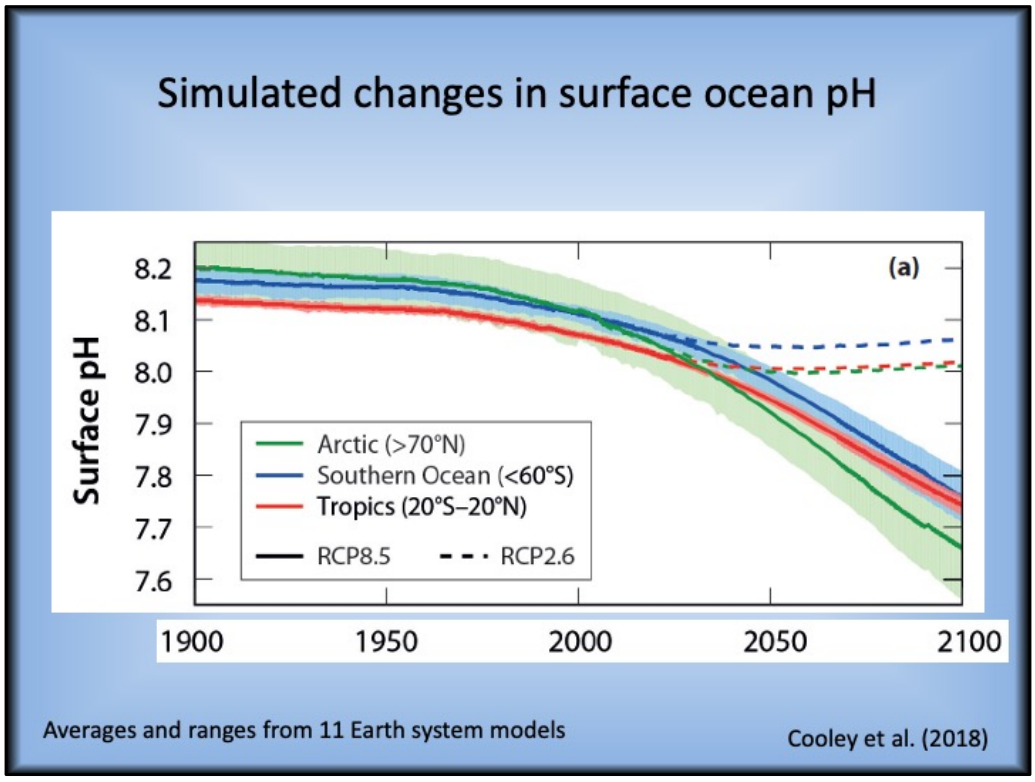
Simulated changes in global-mean sea level





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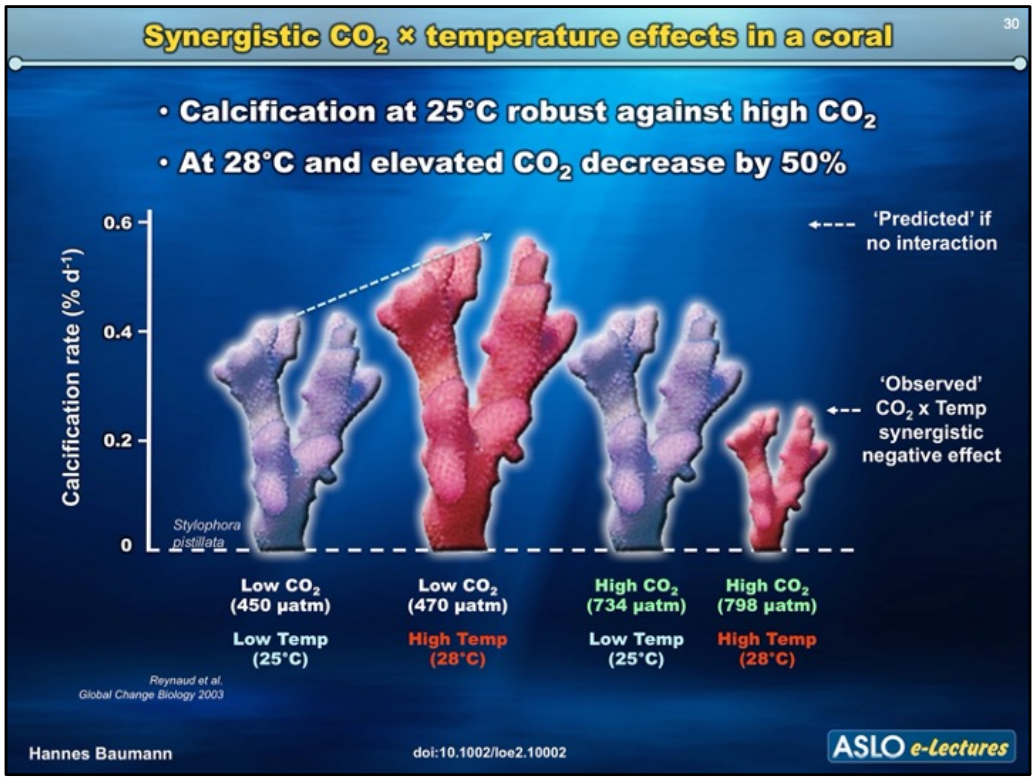

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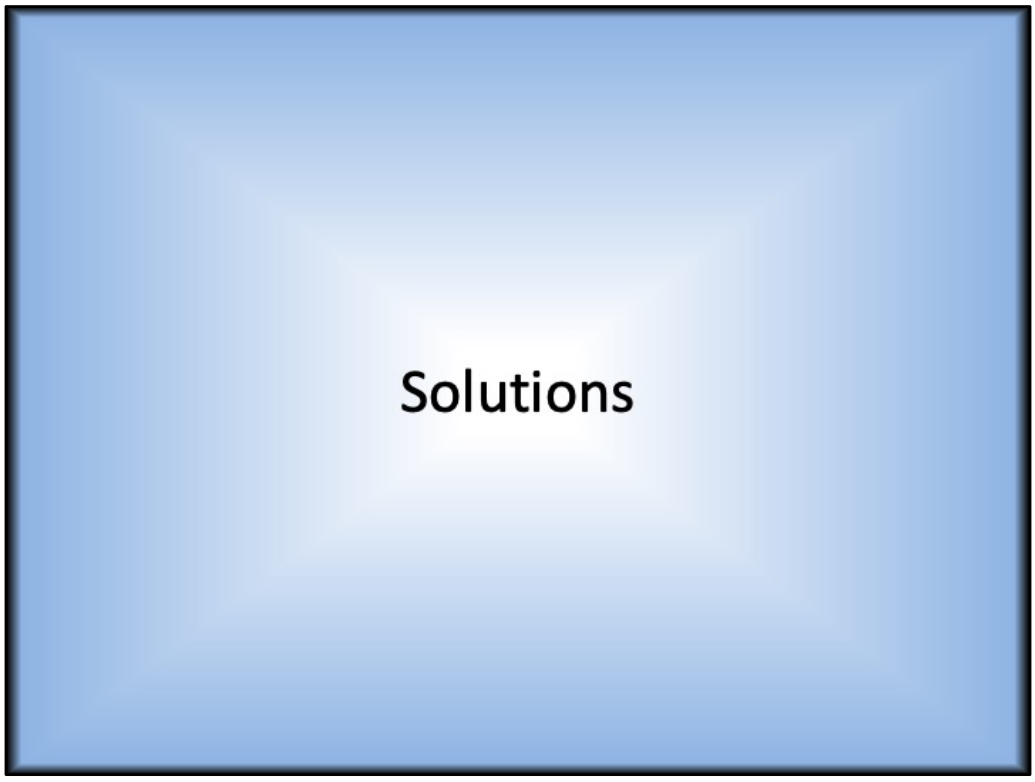
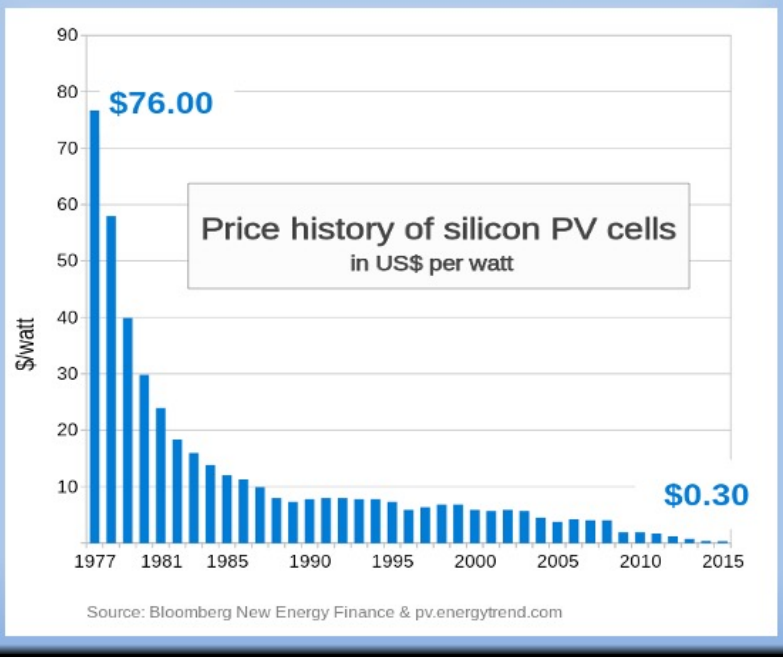
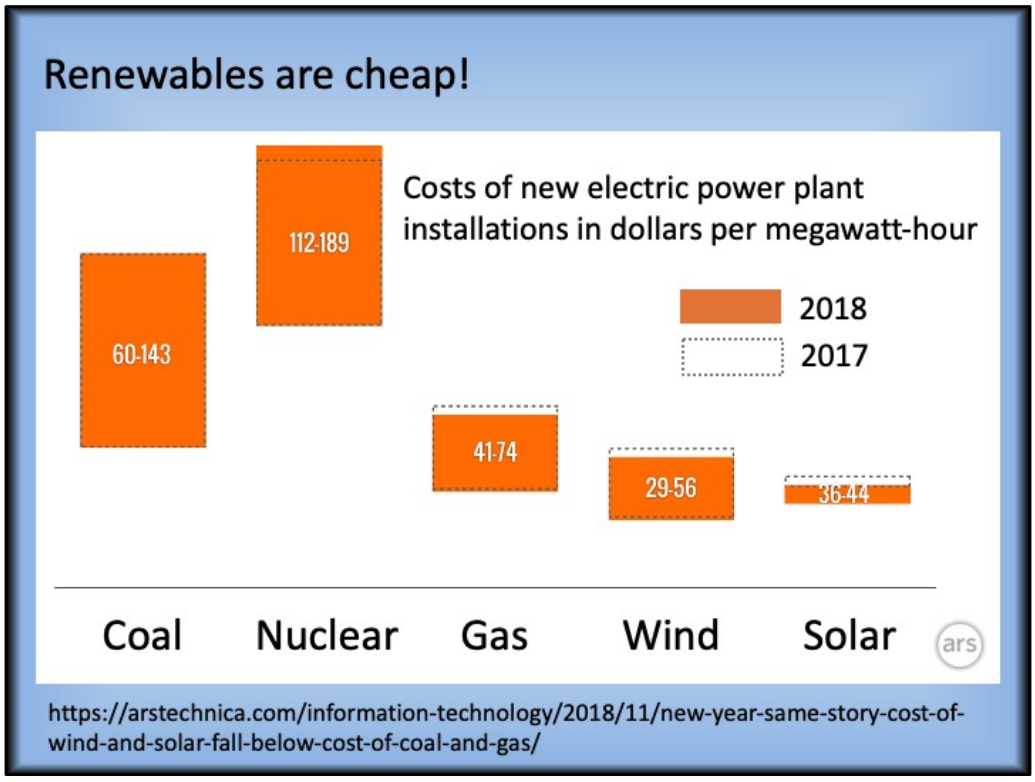
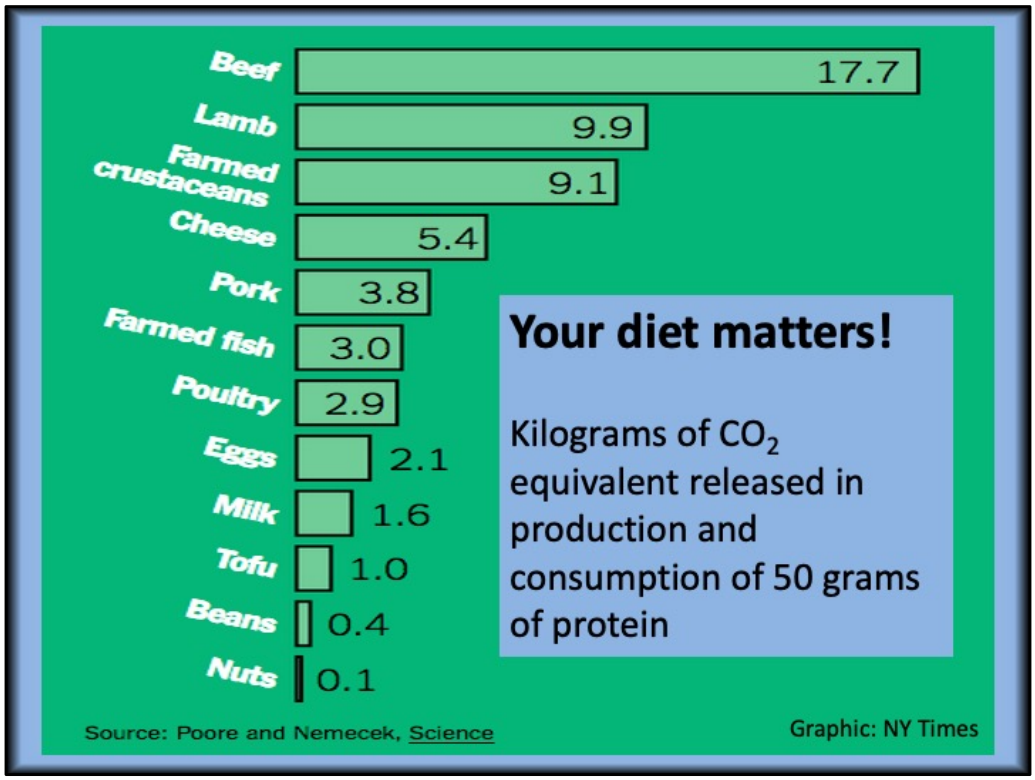

Solutions

The cost to install solar has plummeted





https://arstechnica.com/information-technology/2018/11/new-year-same-story-cost-of-wind-and-solar-fall-below-cost-of-coal-and-gas/



Poore, J., Nemecek, T., 2018. Reducing food's environmental impacts through producers and consumers. Science 360, 987-992.

Graphic: https://www.nytimes.com/interactive/2019/04/30/dining/climate-change-food-eating-habits.html

What if we kept our cars parked for trips less than one mile? In the US, each year we would save

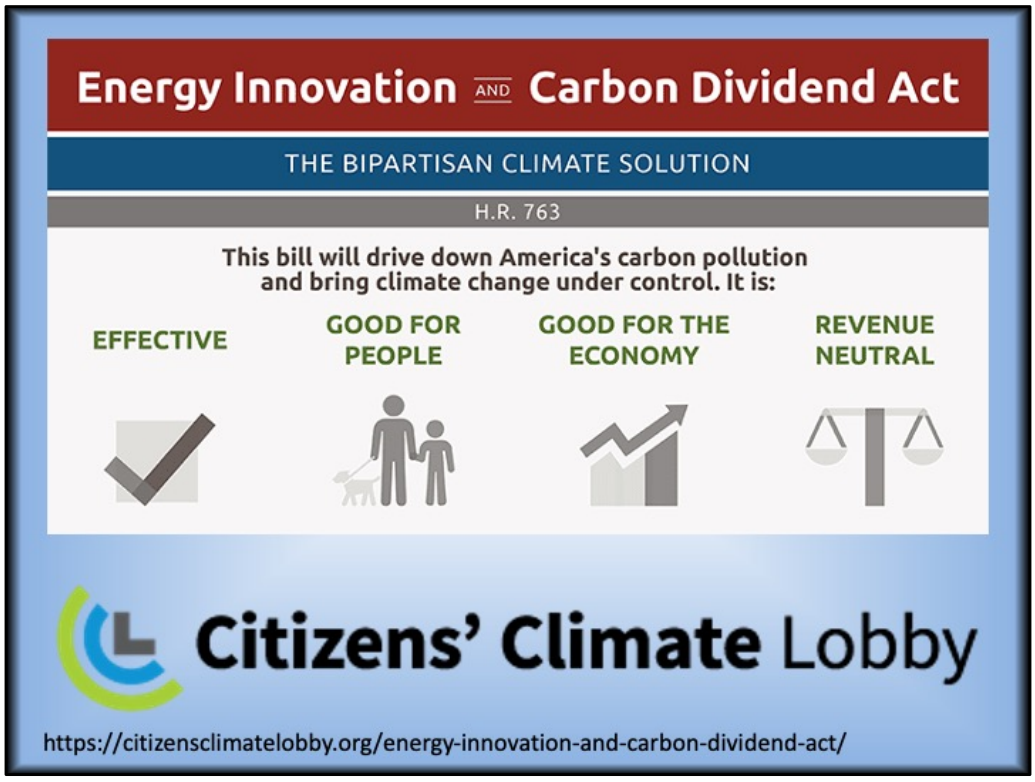
- $900 million in fuel and maintenance costs
- 2 million metric tons of CO_2 emissions

Walkable & bikable communities are healthier and cleaner

https://www.epa.gov/greenvehicles/what-if-we-kept-our-cars-parked-trips-less-one-mile

https://www.epa.gov/greenvehicles/what-if-we-kept-our-cars-parked-trips-less-one-mile

What you can do



https://citizensclimatelobby.org/energy-innovation-and-carbon-dividend-act/

Image source: www.cop21paris.org/

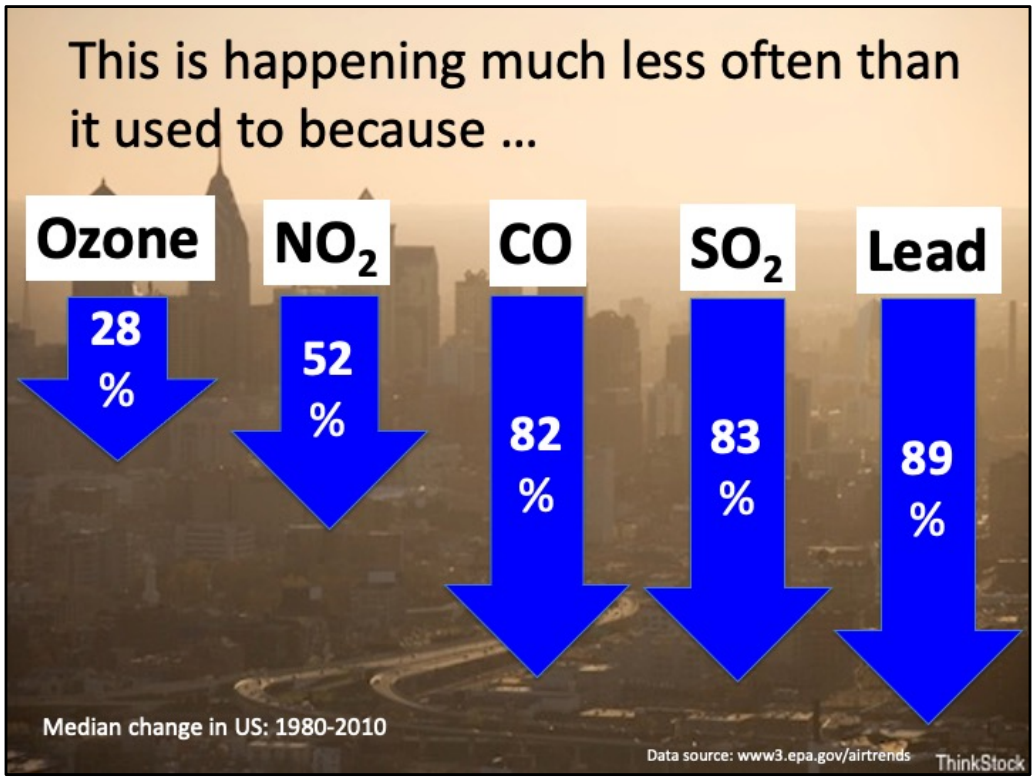
https://www.papowerswitch.com/

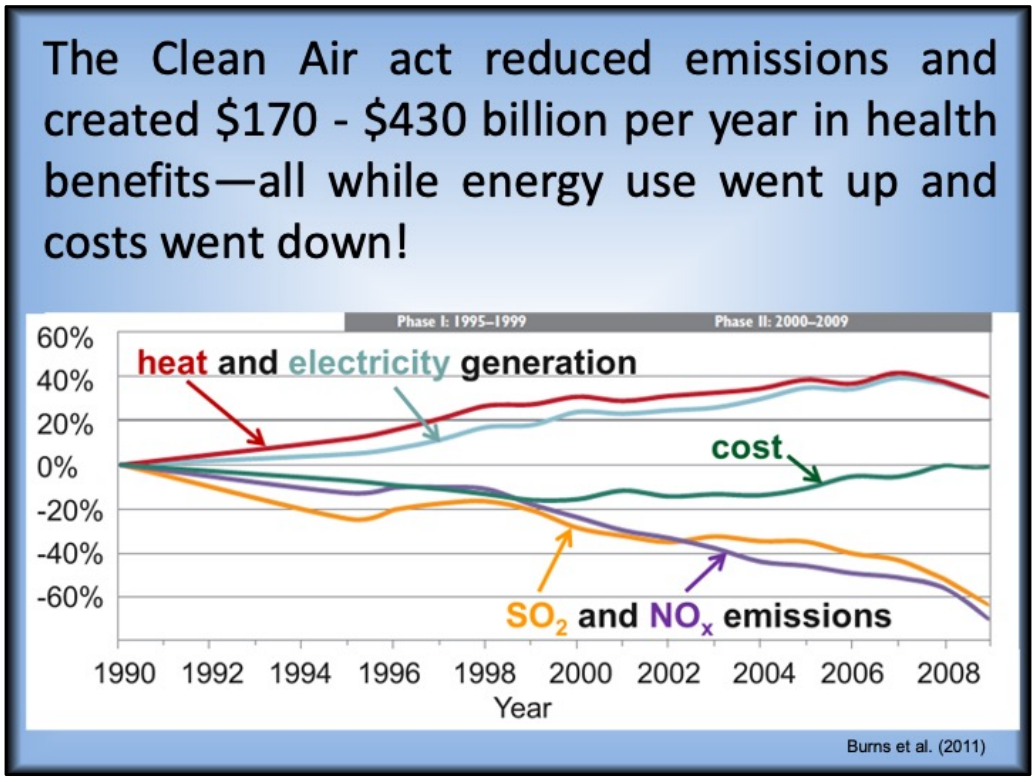
https://www.wesa.fm/post/pa-youth-join-global-student-strike-demand-action-climate-change

Past environmental successes

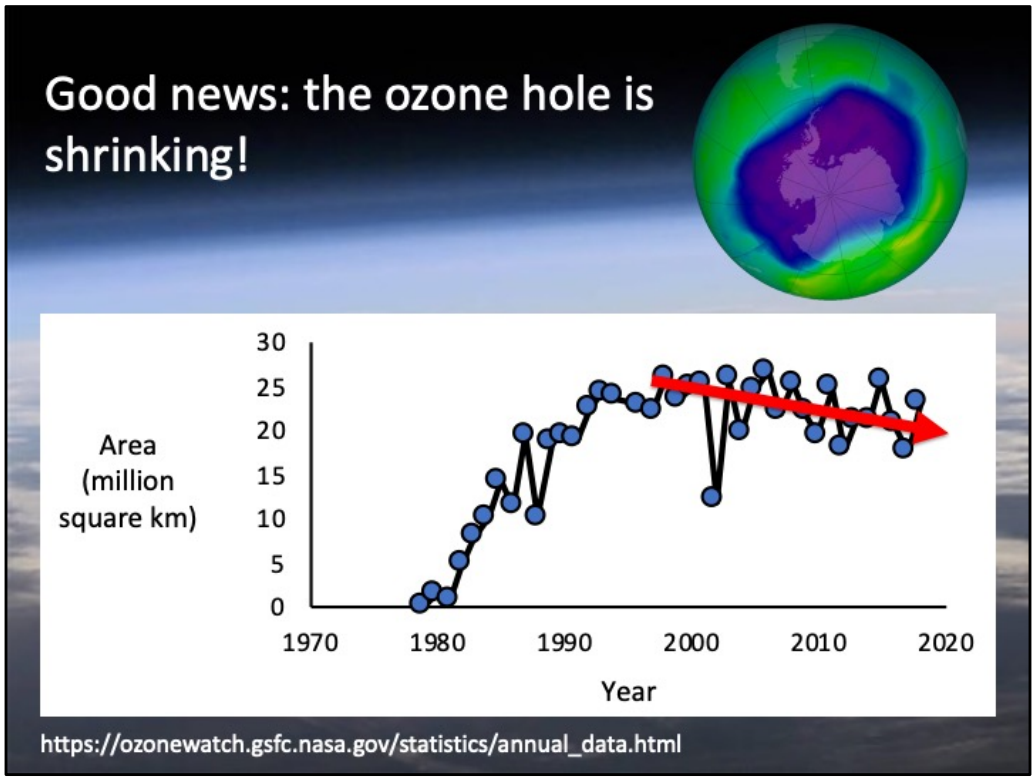
"Smog episodes"

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


This is happening much less often than it used to because …
Ozone
28 %
NO_2
52 %
CO
82 %
SO_2
83 %
Lead
89 %
Median change in US: 1980-2010
Data source: www3.epa.gov/airtrends
ThinkStock

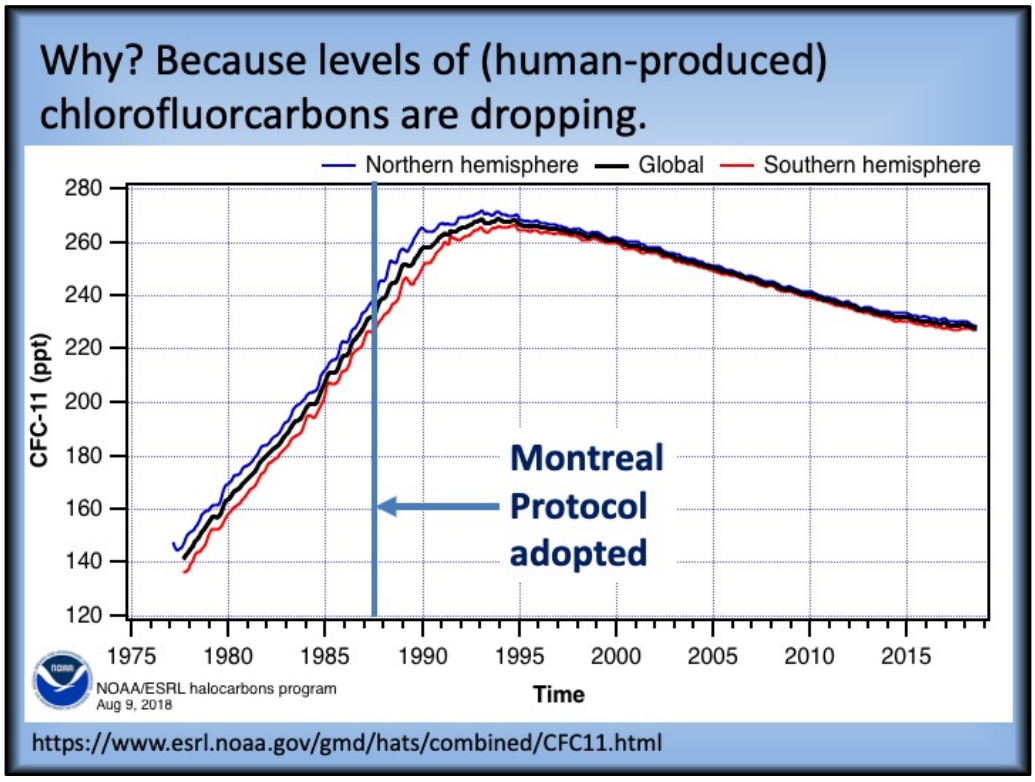


Burns, D.A., Baron, J.S., Cosby, B.J., Fenn, M.E., Lynch, J.A., 2011. National Acid Precipitation Assessment Program Report to Congress 2011: An Integrated Assessment. National Science and Technology Council, United States Government, Washington, D.C., 114 pp.

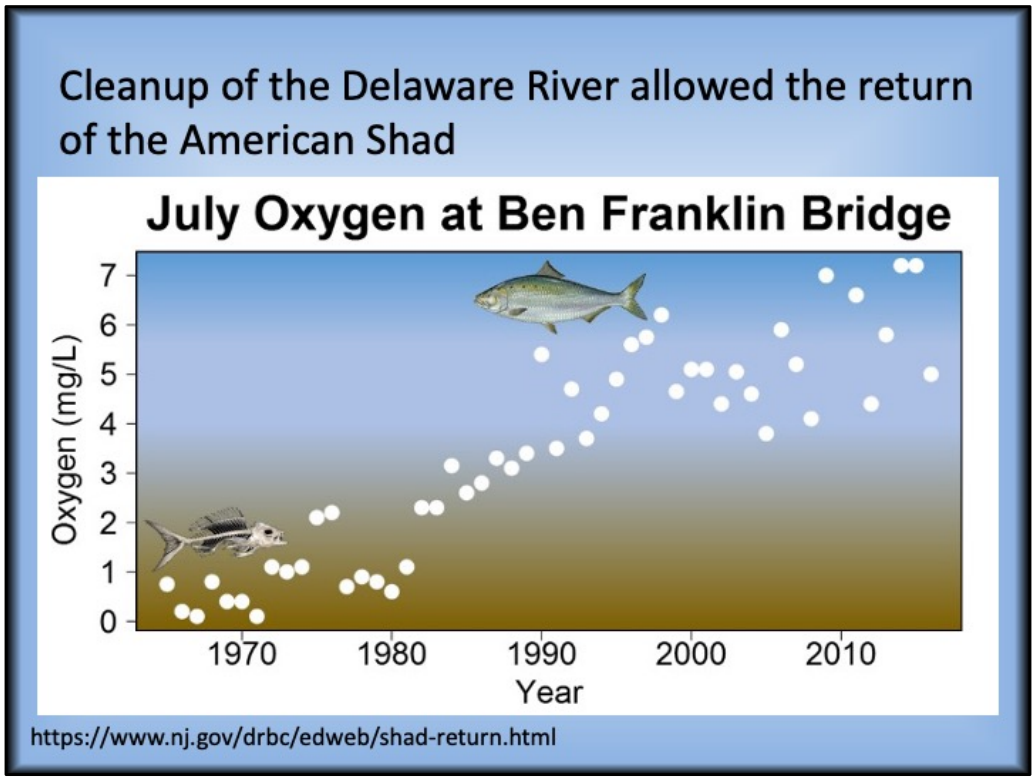


NASA image

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



https://www.esrl.noaa.gov/gmd/hats/combined/CFC11.html



https://www.nj.gov/drbc/edweb/shad-return.html

Take-home messages

1. The ocean is a moderator of the climate
2. Anthropogenic CO_2 emissions have negative impacts of the ocean: warming, sea-level rise, and acidification
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. Solutions are at hand
6. Good science, policy, and business practices have gotten us out of environmental messes before

References

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