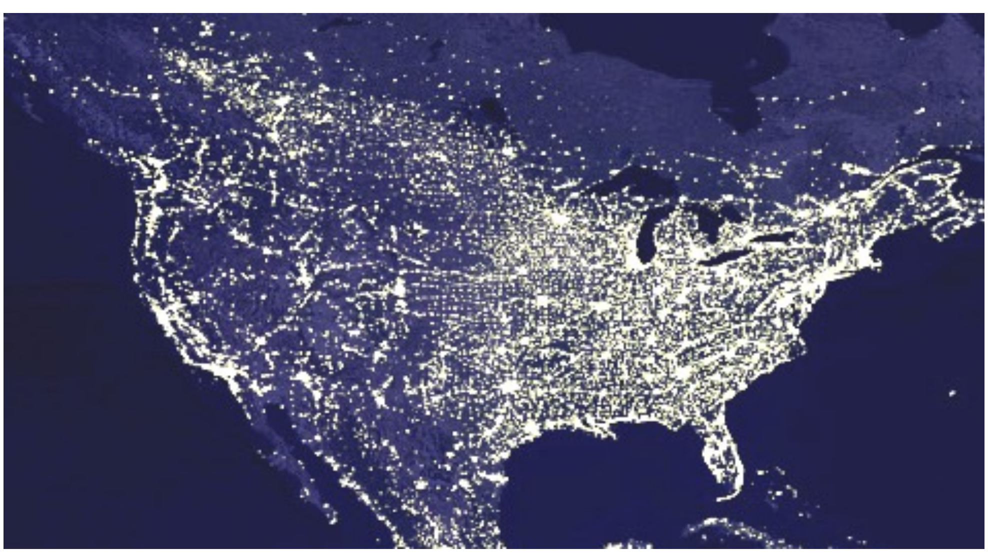
The Real Inconvenient Truth Is That …

Global Change is More Than Global Warming

- Changing atmospheric chemistry
- Changes in global nutrient cycles
- Changing atmospheric composition
- Climate change
- Stratospheric ozone depletion
- Land-use change
- Loss of biodiversity

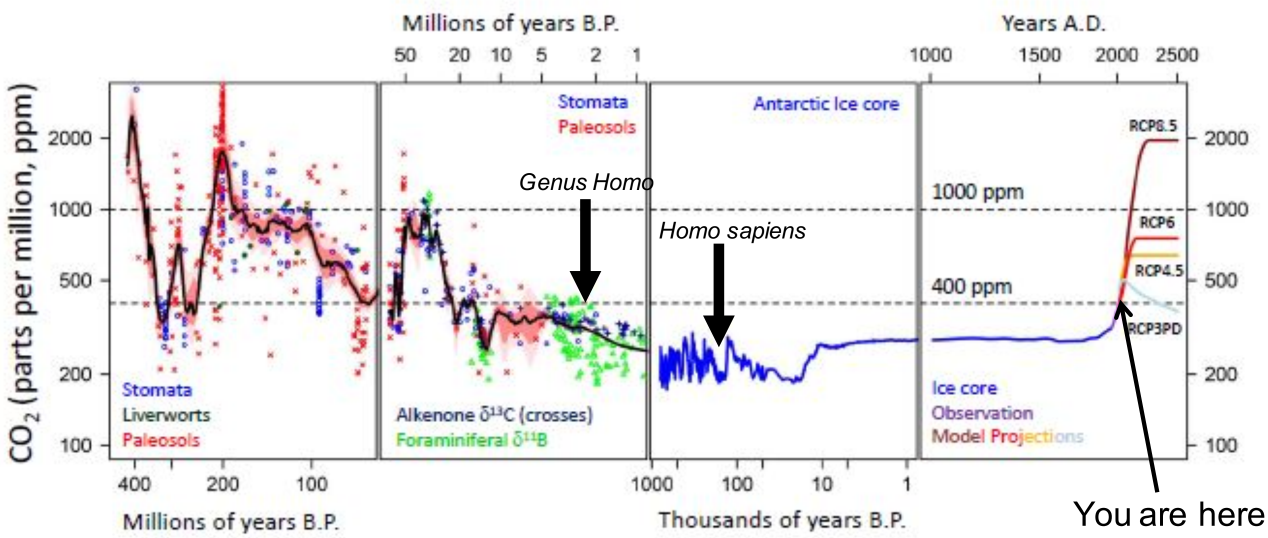
Changes to well-mixed components of the Earth system

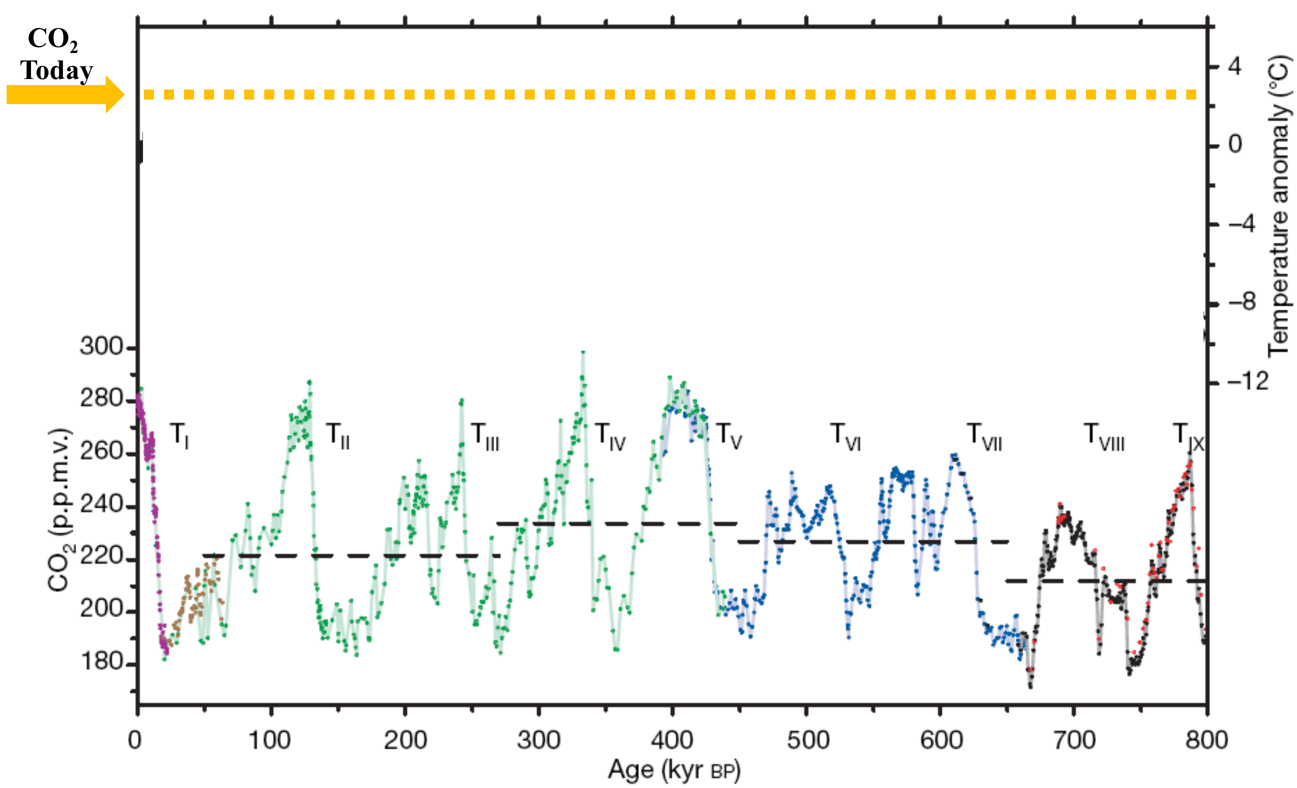
Local Changes that Become Widespread



The atmosphere ain't what it used to be.

At least since we've been around.





Glacial-Interglacial Ice Core Data

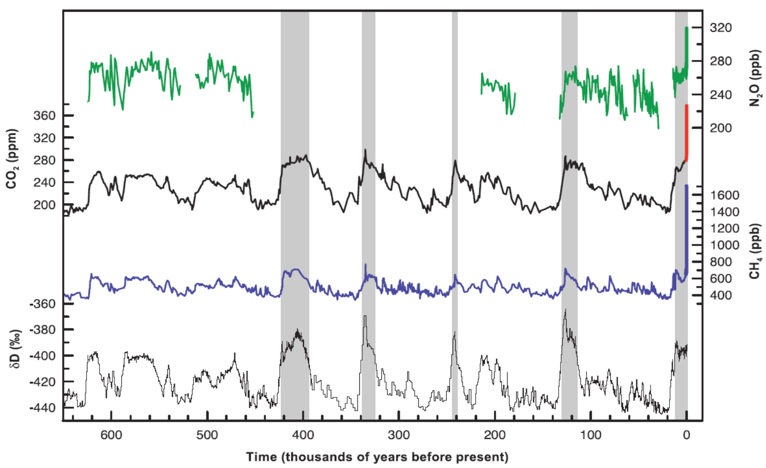


Table 1: Examples of greenhouse gases that are affected by human activities. [Based upon Chapter 3 and Table 4.1]

	CO_2 (Carbon Dioxide)	CH_4 (Methane)	N_2O (Nitrous Oxide)	CFC-11 (Chlorofluoro-carbon-11)	HFC-23 (Hydrofluoro-carbon-23)	CF_4 (Perfluoro-methane)
Pre-industrial concentration	about 280 ppm	about 700 ppb	about 270 ppb	zero	zero	40 ppt
Concentration in 1998	365 ppm	1745 ppb	314 ppb	268 ppt	14 ppt	80 ppt
Concentration in 2017	400	1850	328	220		
Rate of concentration change[b]	1.5 ppm/yr [a]	7.0 ppb/yr [a]	0.8 ppb/yr	−1.4 ppt/yr	0.55 ppt/yr	1 ppt/yr
Overall change	+ 43%	+164%	+21%			
Atmospheric lifetime	5 to 200 yr [c]	12 yr [d]	114 yr [d]	45 yr	260 yr	>50,000 yr

[a] Rate has fluctuated between 0.9 ppm/yr and 2.8 ppm/yr for CO_2 and between 0 and 13 ppb/yr for CH_4 over the period 1990 to 1999.

[b] Rate is calculated over the period 1990 to 1999.

[c] No single lifetime can be defined for CO_2 because of the different rates of uptake by different removal processes.

[d] This lifetime has been defined as an "adjustment time" that takes into account the indirect effect of the gas on its own residence time.

Article

Two-million-year-old snapshots of atmospheric gases from Antarctic ice

Nature 2019 Vol 574

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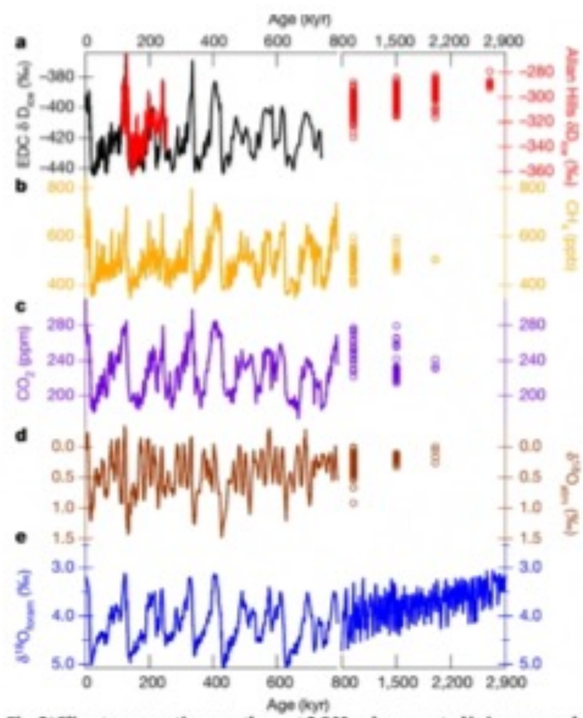
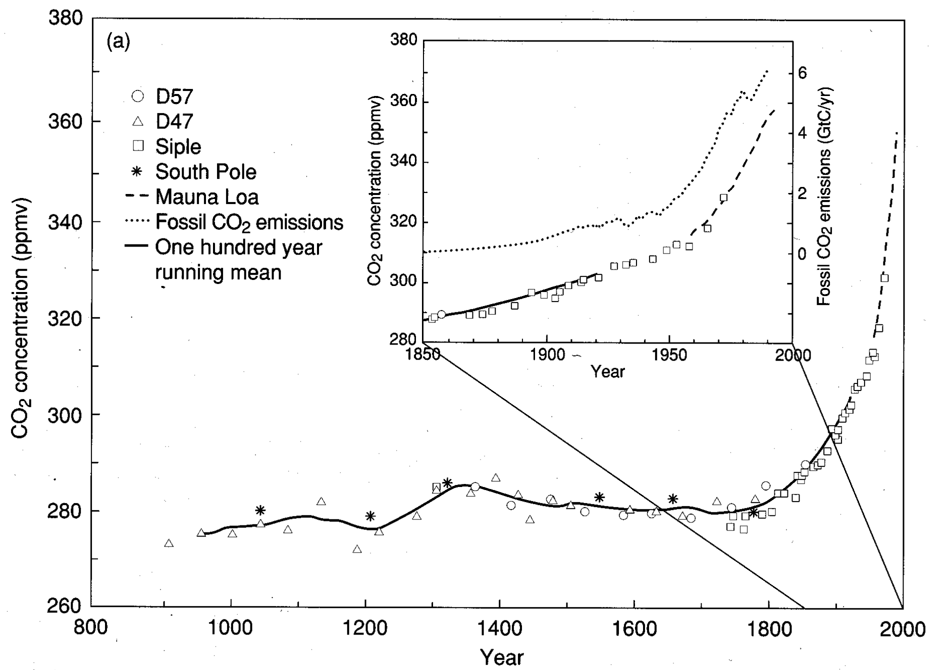
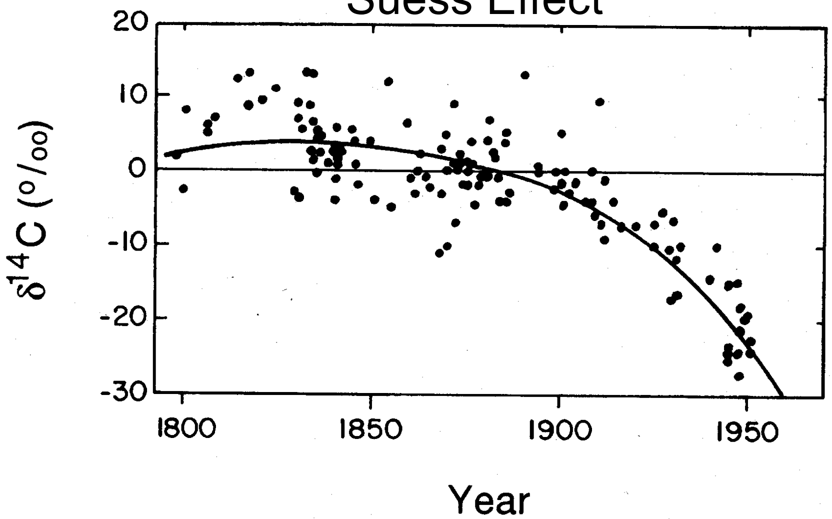


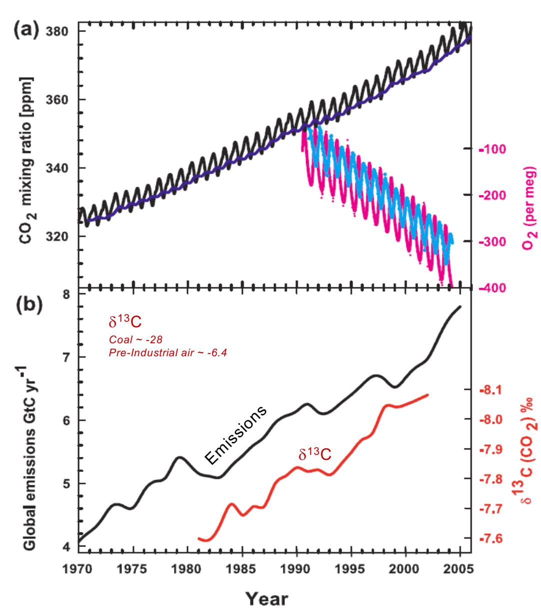
Fig. 2 | Climate properties over the past 2.9 Myr documented in ice core and benthic foram records. a, The continuous 800-kyr δD_{ice} record from the European Project for Ice Coring in Antarctica, Dome C (EDC) ice core[4] (black line); the continuous S27 δD_{ice} record covering 120–250 ka[28] (red line); and the discrete Allan Hills δD_{ice} ice samples (red circles). **b**, The 800-kyr ice core CH_4 record[30] (orange line) and the binned Allan Hills CH_4 data (orange circle). **c**, The 800-kyr ice core CO_2 record[3,5,6,29] (purple line) and the binned Allan Hills CO_2 data (purple circles). Note that there are no reliable CO_2 and CH_4 analyses in the 2.7-Ma bin (see Methods). **d**, The 800-kyr ice core $\delta^{18}O_{atm}$ record[29,30] (brown line) and binned values of Allan Hills $\delta^{18}O_{atm}$ samples (brown circles). All $\delta^{18}O_{atm}$ values are normalized to the modern atmosphere. **e**, The globally distributed benthic oxygen isotope stack over the Plio-Pleistocene (LR04)[2] showing decreased glacial–interglacial variability and less extreme glacials before 800 ka.

Why blame us?

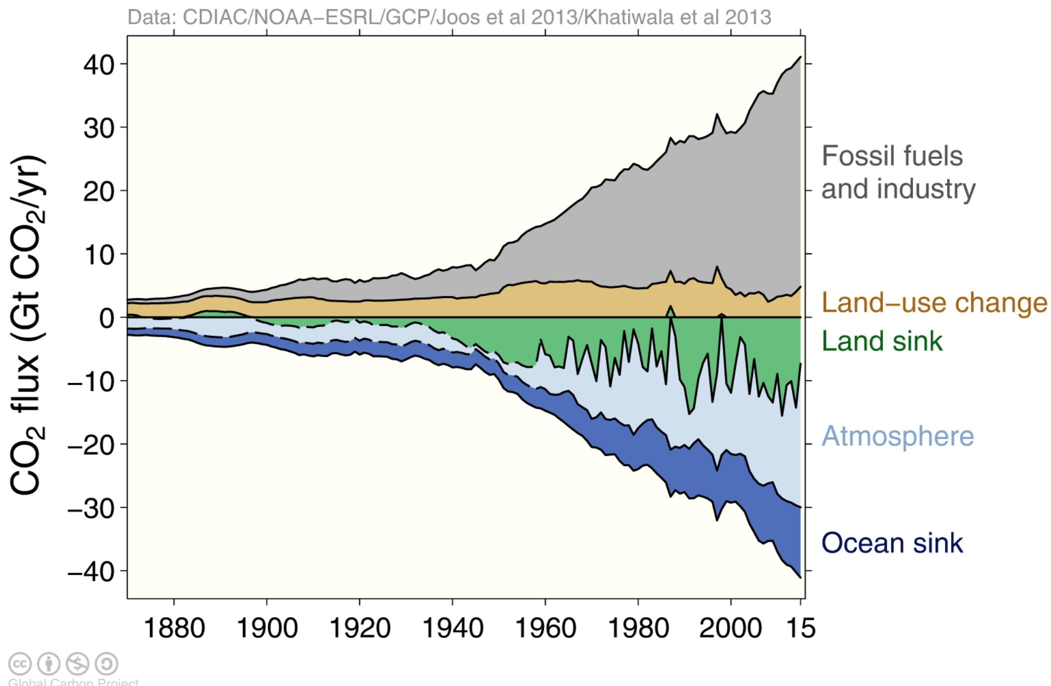


Suess Effect





Net Sources & Sinks Over Time



Sources by activity & country

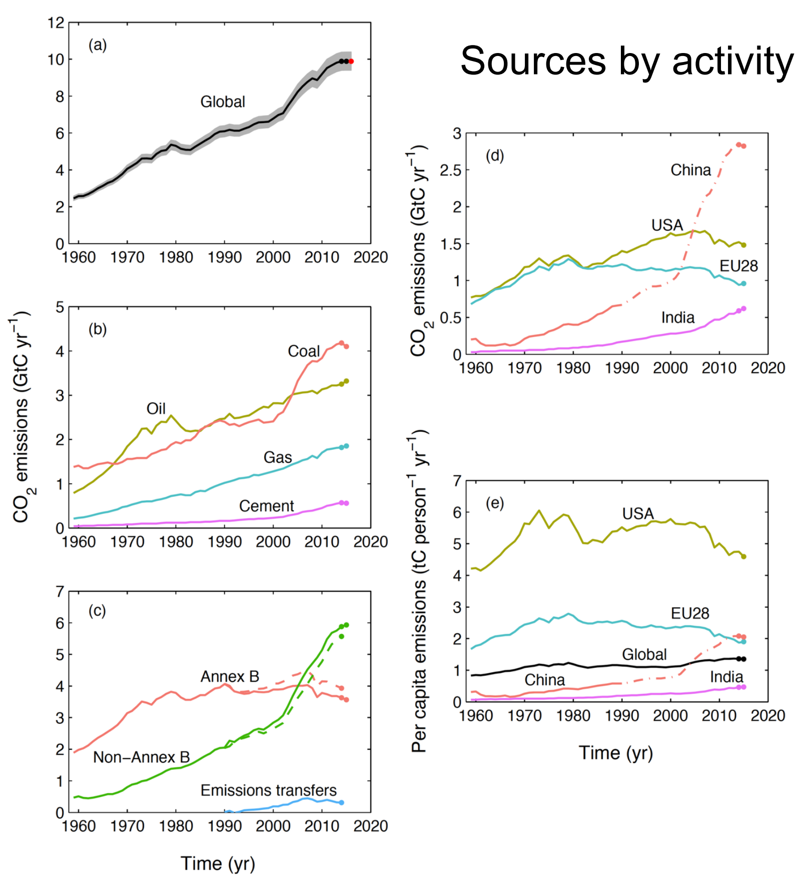


TABLE 11.2 Estimated Sources and Sinks of Methane in the Atmosphere in 2010

Natural sources	Flux (10^{12} g CH_4/yr)		References
Wetlands	143		Neef et al. 2010
Tropics		46	Bloom et al. 2010
Northern latitude		20	Christensen et al. 1996
Upland vegetation	10 (estimate)		Megonigal and Guenther 2008; Kirschbaum et al. 2006
Termites	19		Sanderson 1996
Oceans	10		Reeburgh 2007
Geological seepage[a]	33		Etiope et al. 2008
Anthropogenic sources			
Fossil fuel related	20-30% Total Flux		
Coal mines	30		Prather et al. 1995
Coal combustion	15		Prather et al. 1995
Oil and gas	72		Neef et al. 2010
Waste and waste management			
Landfills	18		Bogner and Matthews 2003
Animal waste	25		Prather et al. 1995
Sewage treatment	25		Prather et al. 1995
Ruminants	116		Neef et al. 2010
Reservoirs	70		St. Louis et al. 2000
Biomass burning	19		Kaiser et al. 2012
Rice cultivation	40		Sass and Fisher 1997, Bloom et al. 2010
Total sources	**645**		
Sinks			
Reaction with OH radicals	522		Neef et al. 2010
Removal in the stratosphere	34		Neef et al. 2010
Removal by soils	25		Curry 2007 Dutaur and Verchot 2007
Total sinks	**581**		
Atmospheric increase (2007)	23		Dlugokencky et al. 2009

Note: All data in 10^{12} g CH_4/yr from various sources as cited here and in the text.
[a] *Total geological seepage less marine.*

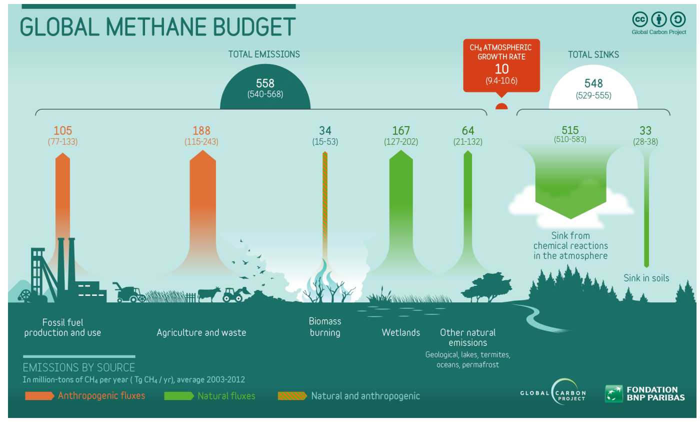


TABLE 12.5 A Global Budget for Nitrous Oxide (N_2O) in the Atmosphere (all values are Tg N/yr (10^{12} g/yr) nitrogen, as N_2O)

Natural sources	Annual flux	References
Soils	3.4 ± 1.3	Zhuang et al. 2012[a]
Ocean surface	6.2 ± 3.2	Bianchi et al. 2012
Total natural	9.6	
Anthropogenic sources		
Agricultural soils	2.8	Bouwman et al. 2002b[b]
Cattle and feed lots	2.8	Davidson 2009
Biomass burning	0.9	Kaiser et al. 2012
Industry and transportation	0.8	Davidson 2009
Human sewage	0.2	Mosier et al. 1998
Total anthropogenic	7.5	
Total sources	**17.1**	
Sinks		
Stratospheric destruction	12.3	Prather et al. 1995
Uptake by soils	<0.1	Syakila and Kroeze 2011
Atmospheric increase	4.0	IPCC 2007
Total identified sinks	**16.4**	

[a] *Alternative estimates for the flux of N_2O from natural soils includes 6.1 Tg N/yr (Potter et al. 1996) and 6.6 Tg N/yr (Bouwman et al. 1995).*
[b] *The sum of emissions from agriculture and domestic animals given here, 5.6 Tg N/yr, is in close agreement with the value of 5.0 Tg N/yr estimated by Syakila and Kroeze (2011). These estimates of N_2O flux from agricultural activities include emissions of N_2O from downstream ecosystems and groundwaters impacted by agricultural inputs in these regions.*

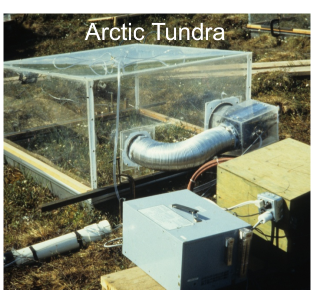
Changes in atmospheric composition can affect more than just climate.

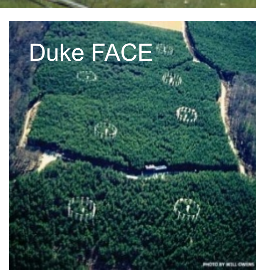
Increased CH_4 → Increase tropospheric O_3

Increased N_2O → Decreases stratospheric O_3

Increased CO_2 → Plants & Ocean acidity

Effects on plants have been studied many ways.





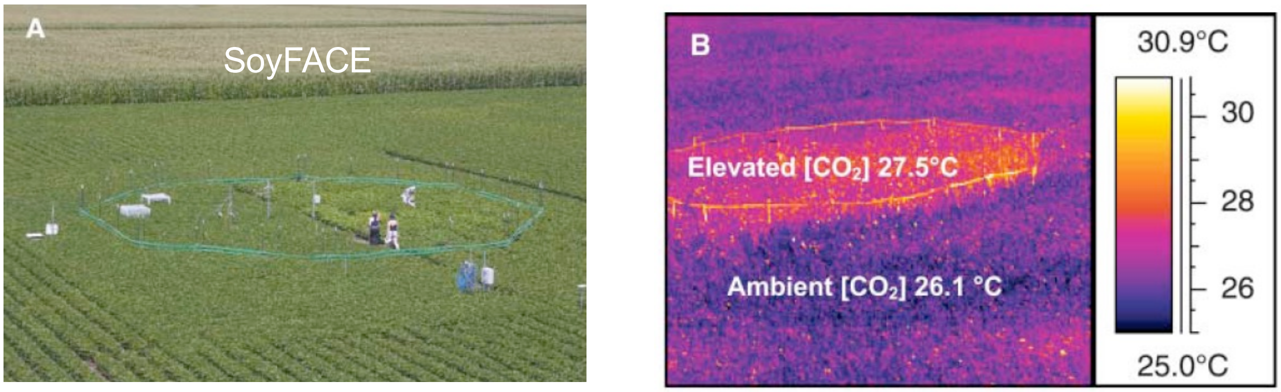
Effects on plants include:

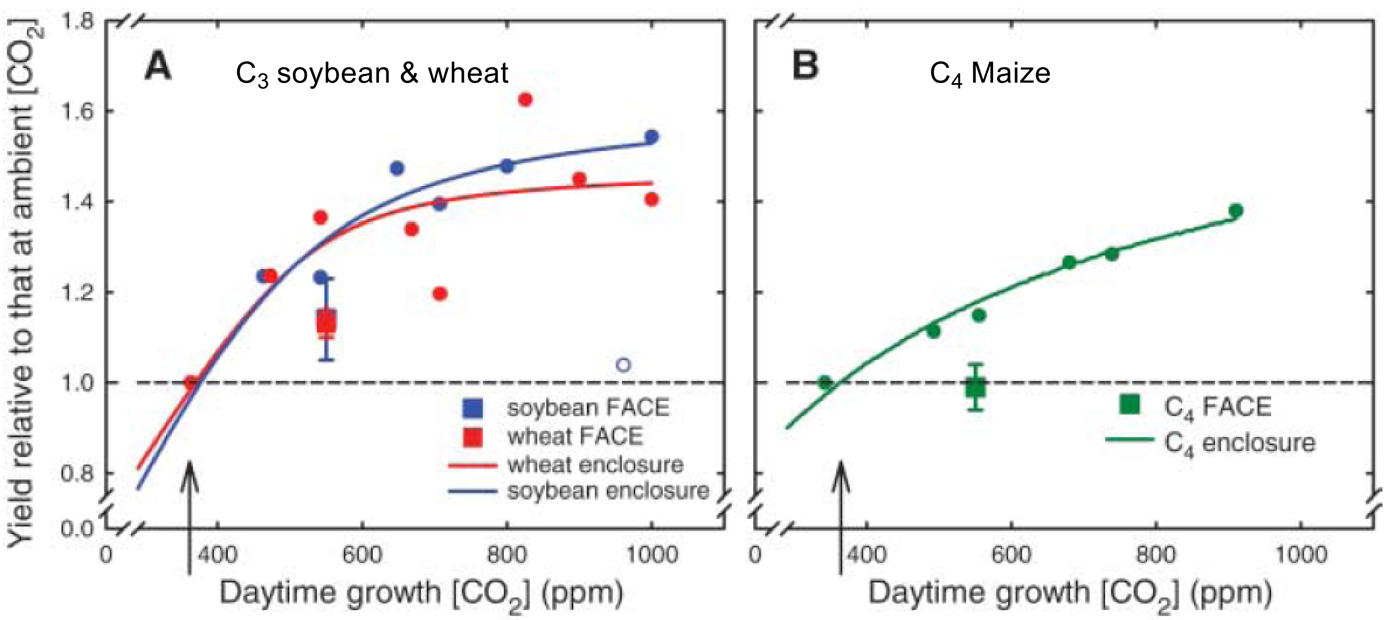
Altered physiology
Competition
Herbivory
Phenology

↑ CO_2 → ↓ stomatal apeture → ↓ transpiration → ↑ WUE ← $\frac{P_s}{\text{Transpiration}}$

↳ ↑ soil moisture + ↑ canopy temp.

↓ effects of gaseous air pollutants like O_3

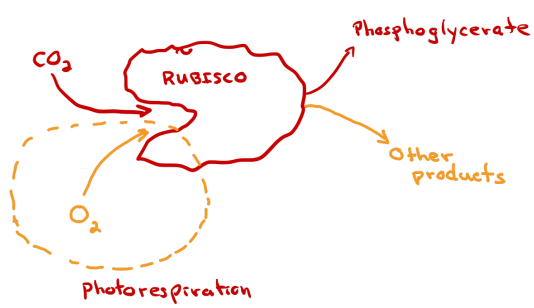




Long et al. 2006

↑ CO_2 → ↑ P_s efficiency → ↑ P_s BUT ...

↳ due to ↓ photorespiration in C_3 plants



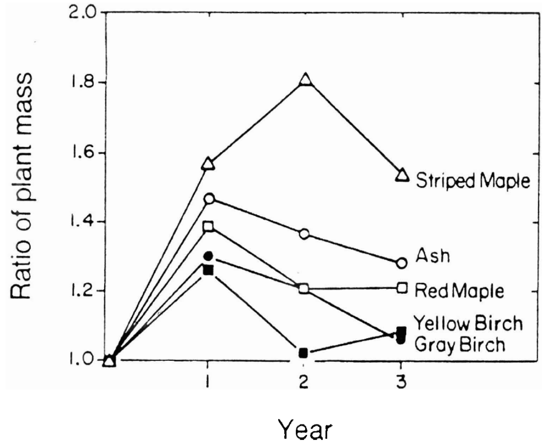
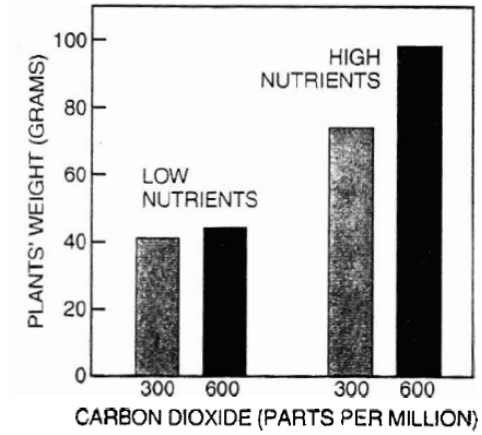


FIG. 6. The time course of growth enhancement caused by elevated CO_2 concentration for several New England tree species. The response ratio is calculated as growth of a given species at 680 μL/L CO_2 divided by its growth at 340 μL/L CO_2. All of the species initially respond positively, but they differ substantially in how long elevated growth rates are maintained. From Bazzaz et al. (1994); reproduced with permission.

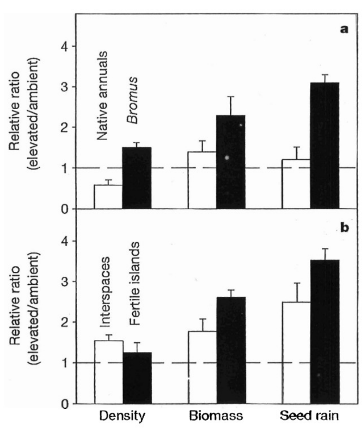
Vitousek 1994



CO_2 FERTILIZATION EFFECT depends on the supply of nutrients to the ecosystem. The biomass of a group of plants did not increase in high CO_2 levels unless sufficient nutrients were added.

Bazzaz & Fajer 1992

CO_2 May Alter Competitive Balance Between Native & Introduced Species



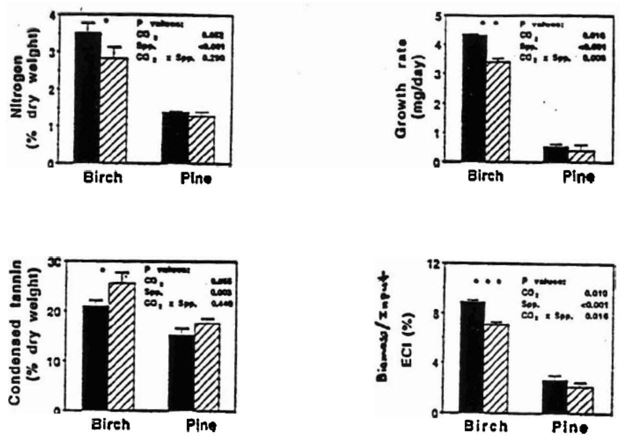
Smith et al. 2000

Oecologia (1994) 98:133–138

ORIGINAL PAPER

Sherry K. Roth · Richard L. Lindroth

Effects of CO_2-mediated changes in paper birch and white pine chemistry on gypsy moth performance



Near Ambient CO_2

Elevated CO_2

Production of allergenic pollen by ragweed (*Ambrosia artemisiifolia* L.) is increased in CO_2-enriched atmospheres

Peter Wayne, PhD*; Susannah Foster, BS*; John Connolly, PhD†; Fakhri Bazzaz, PhD*; and Paul Epstein, MD‡

Annals of Allergy, Asthma and Immunology 2002;8:279-282.

Background: The potential effects of global climate change on allergenic pollen production are still poorly understood.

Objective: To study the direct impact of rising atmospheric CO_2 concentrations on ragweed (*Ambrosia artemisiifolia* L.) pollen production and growth.

Methods: In environmentally controlled greenhouses, stands of ragweed plants were grown from seed through flowering stages at both ambient and twice-ambient CO_2 levels (350 vs 700 $\mu L\ L^{-1}$). Outcome measures included stand-level total pollen production and end-of-season measures of plant mass, height, and seed production.

Results: A doubling of the atmospheric CO_2 concentration stimulated ragweed-pollen production by 61% ($P = 0.005$).

Conclusions: These results suggest that there may be significant increases in exposure to allergenic pollen under the present scenarios of global warming. Further studies may enable public health groups to more accurately evaluate the future risks of hay fever and respiratory diseases (eg, asthma) exacerbated by allergenic pollen, and to develop strategies to mitigate them.

Annals of Allergy, Asthma, & Immunology ©2002;88:279-282.

Poison ivy causes ~350,000 cases of contact dermatitis per year.

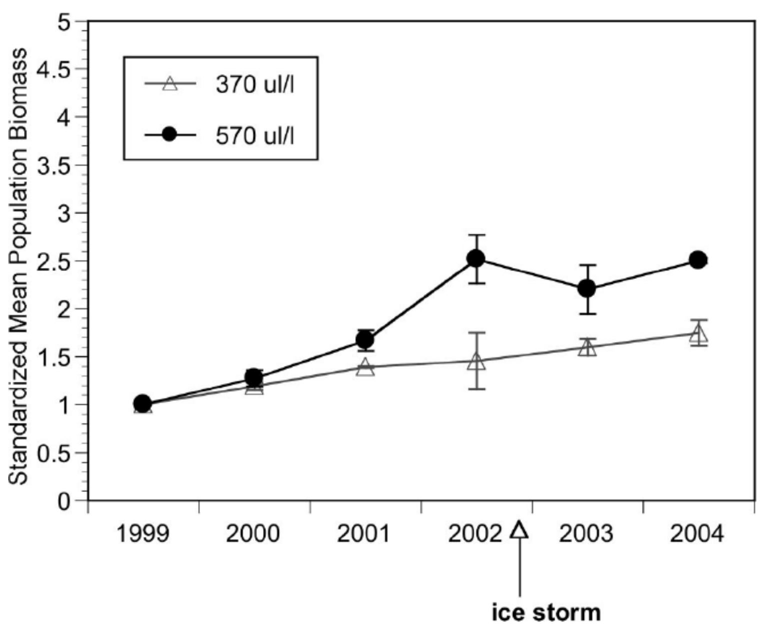
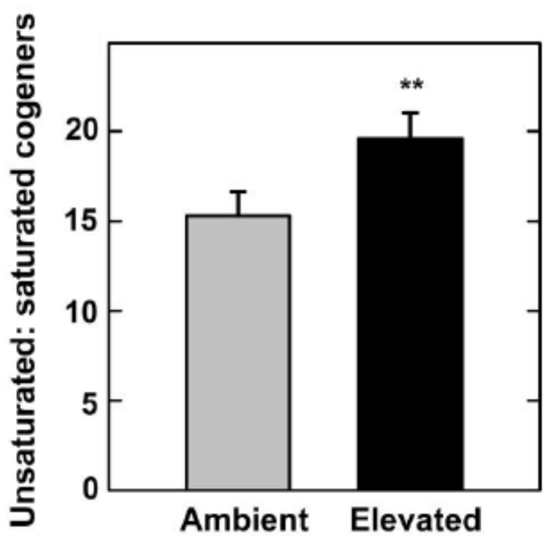
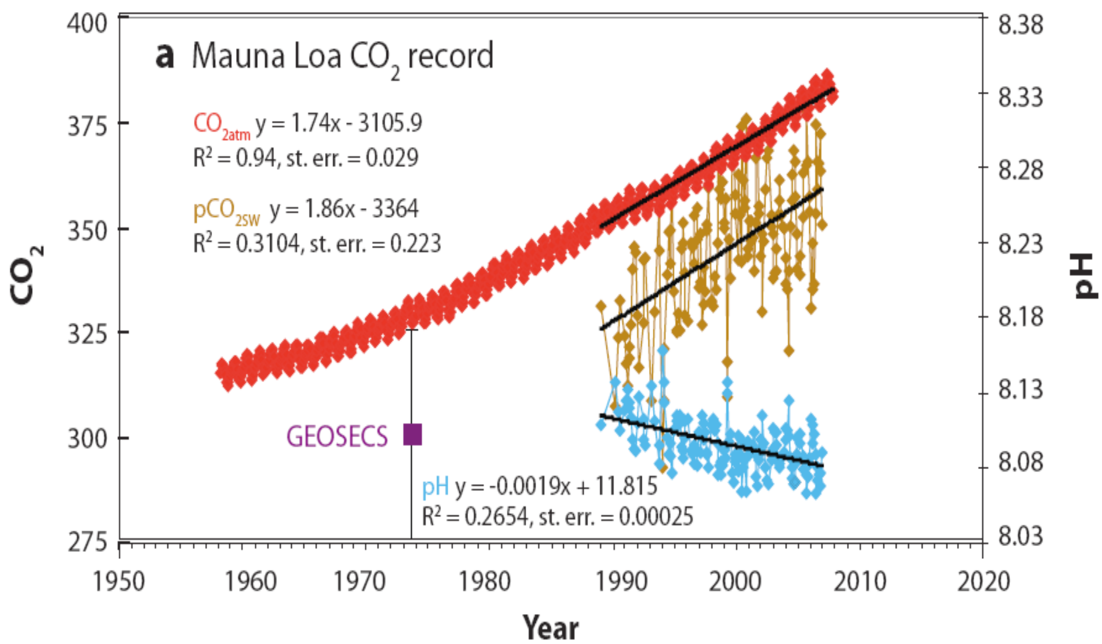


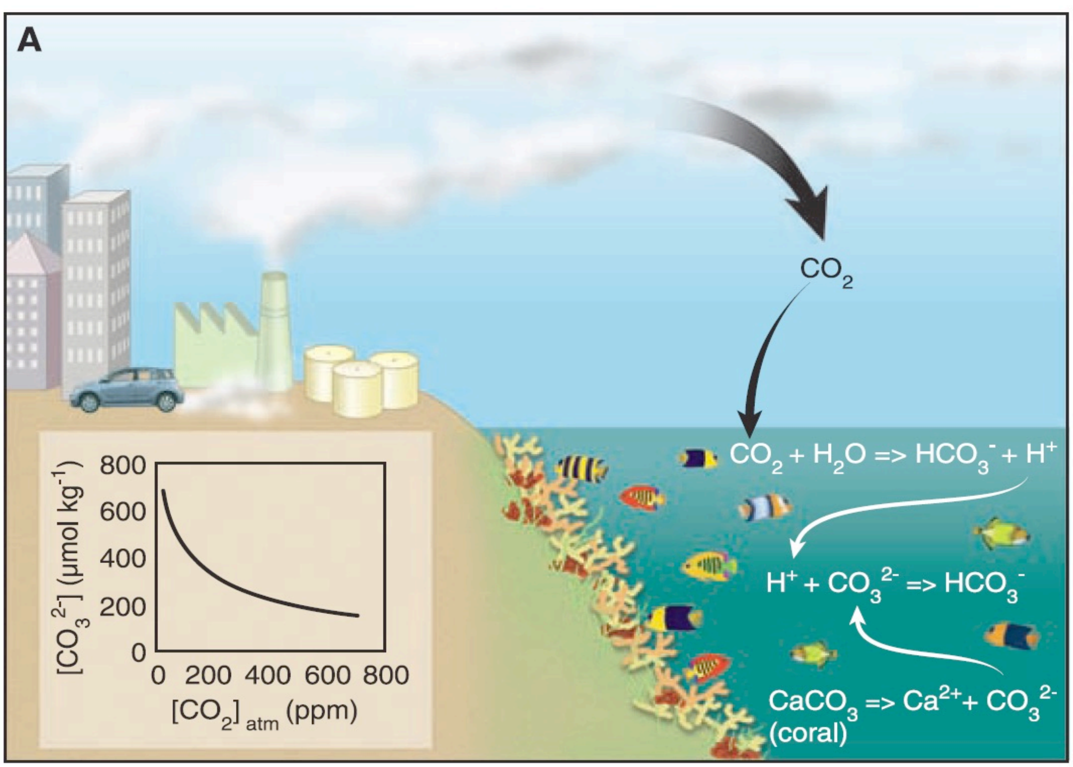
Fig. 2. Mean population biomass standardized by dividing by the initial plot biomass in 1999 ($n = 3$). Error bars denote ±1 SE. The rate of increase is greater at elevated CO_2 ($P = 0.046$ in a repeated-measures analysis).

The higher the ratio of [unsaturated: saturated] variants, the more allergenic urushiol is to humans



Mohan et al. 2006



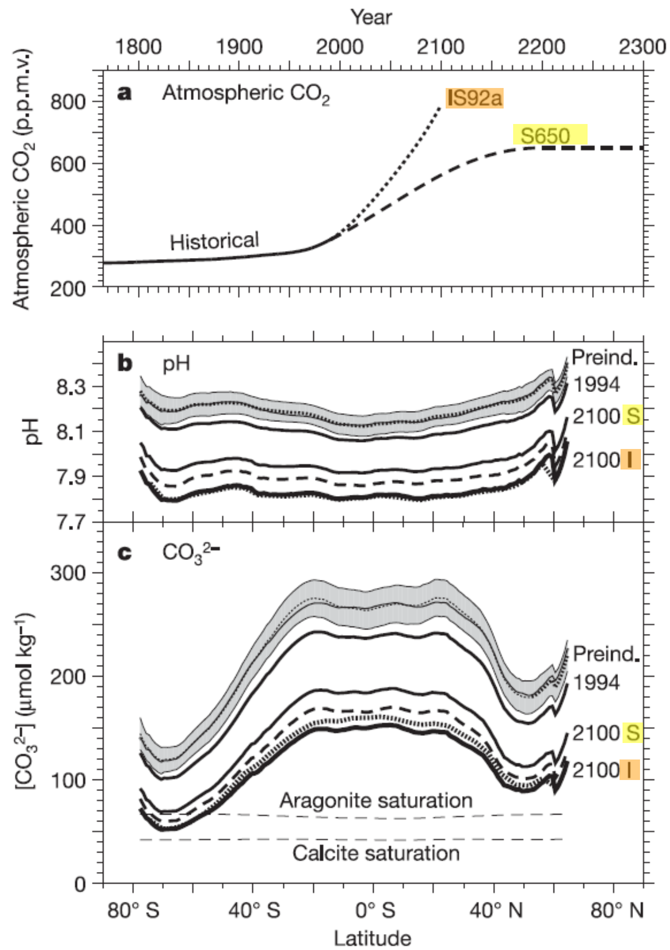


$$CO_2 + CO_3^{=} + H_2O \Leftrightarrow 2\ HCO_3^-$$

$$HCO_3^- \Leftrightarrow H^+ + CO_3^{=}$$

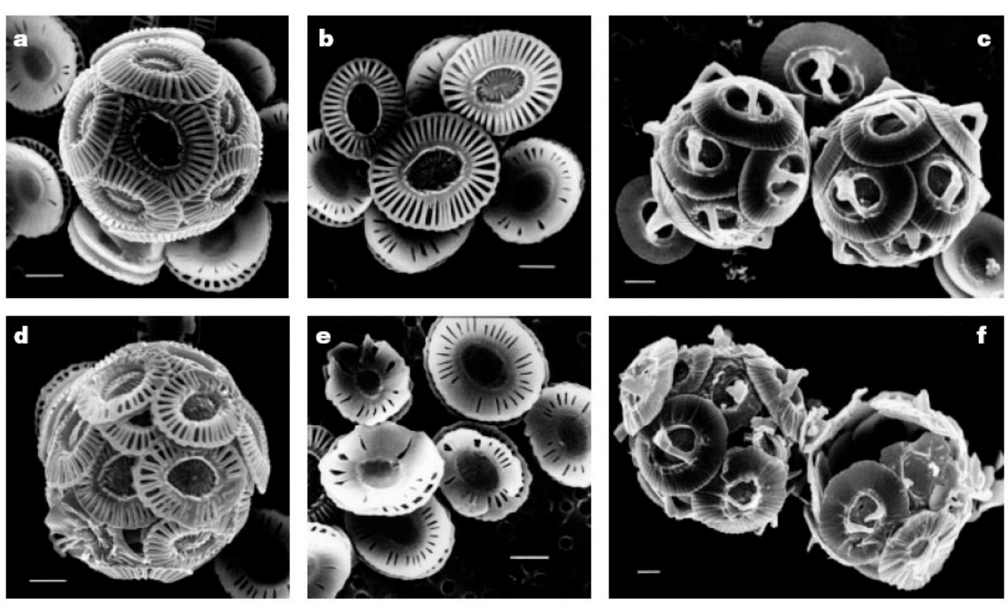
$$pCO2 = KCO2 \times \left(\frac{[HCO_3]^2}{[CO_3]}\right)$$

$$[H] = \frac{k_2[HCO_3]}{[CO_3]}$$



Orr et al. 2005

Reduced calcification of marine plankton in response to increased atmospheric CO_2

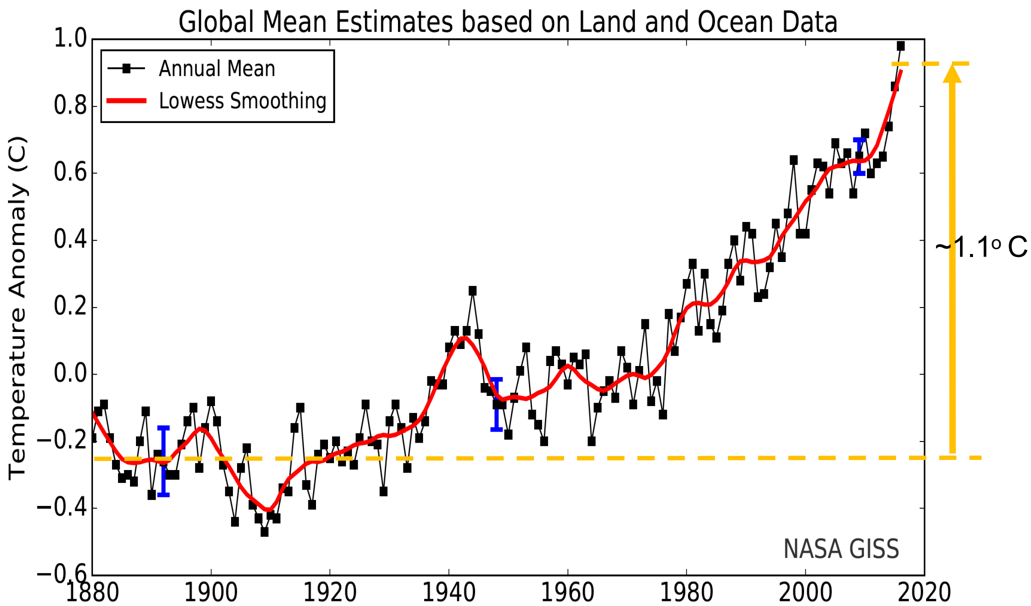


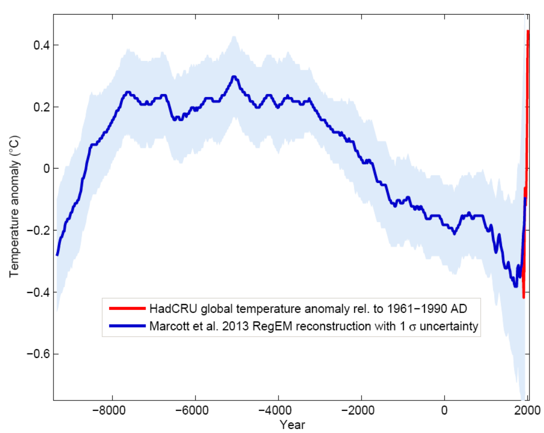
$[CO_2]$ ~12 uM

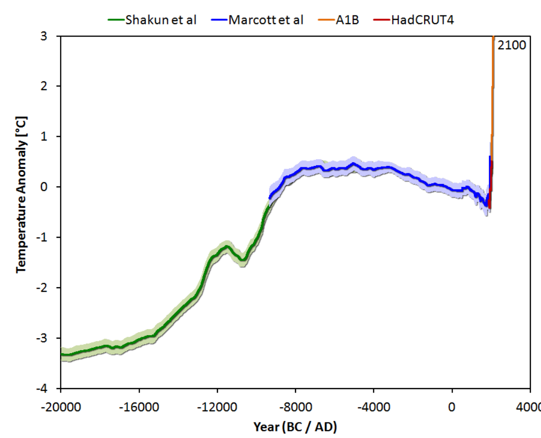
$[CO_2]$ ~30 uM

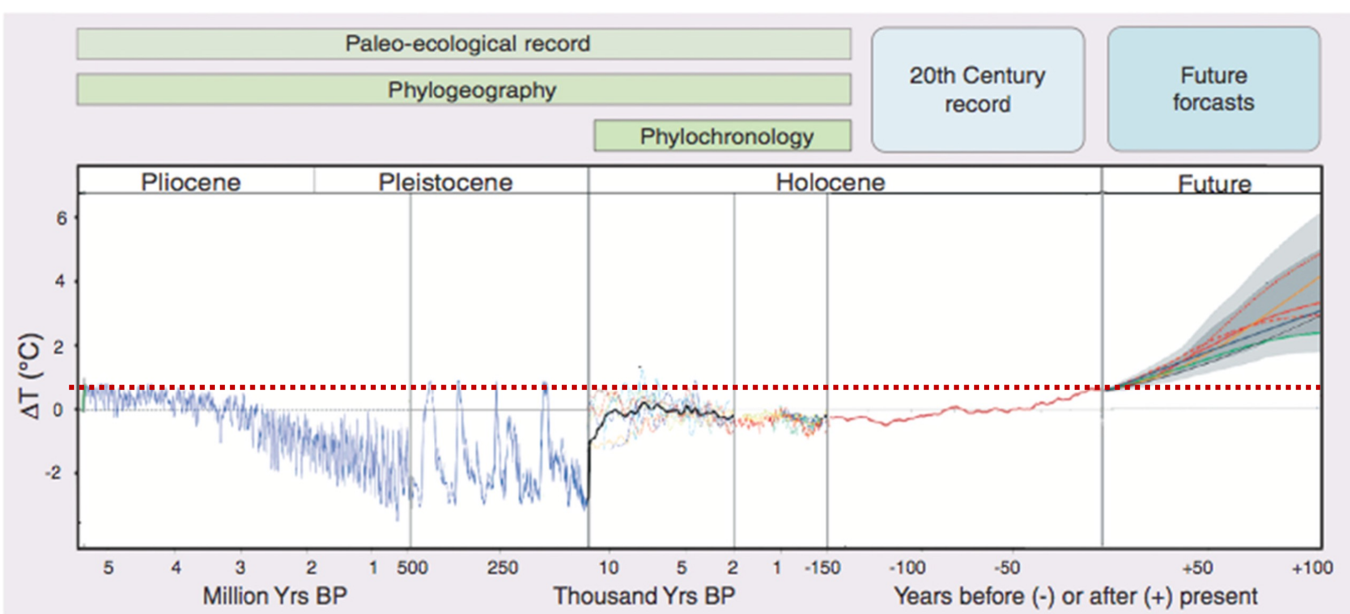
Riebesell et al. 2000

The world is warmer.

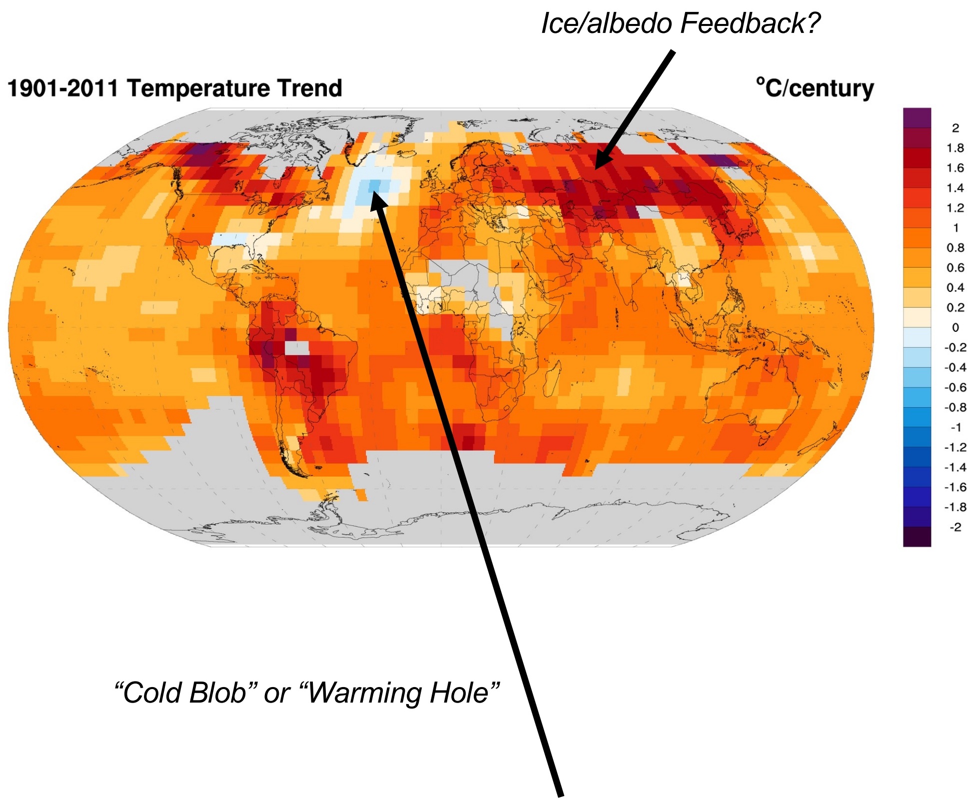




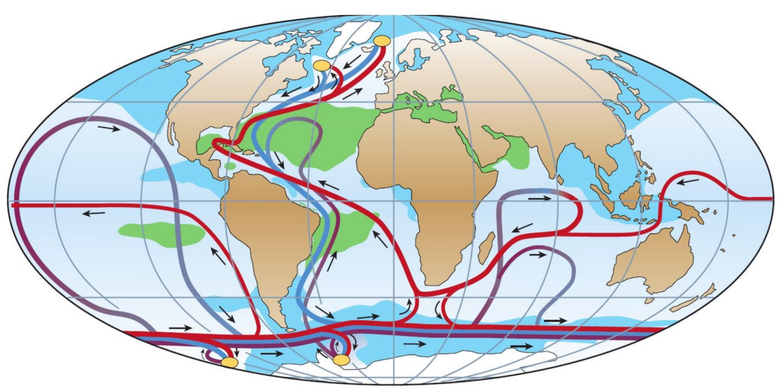




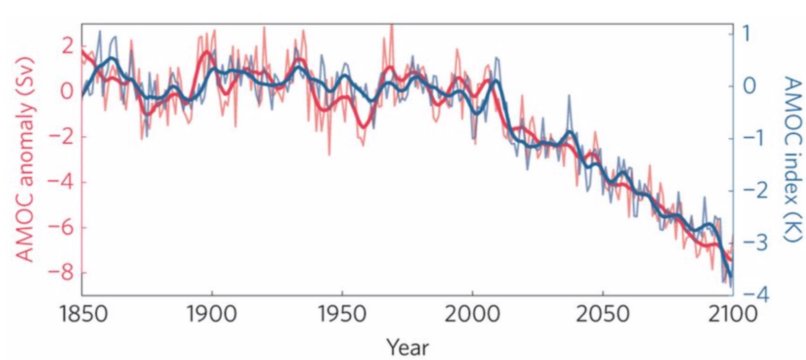
Not everywhere has warmed the same amount.



AMOC may be slowing

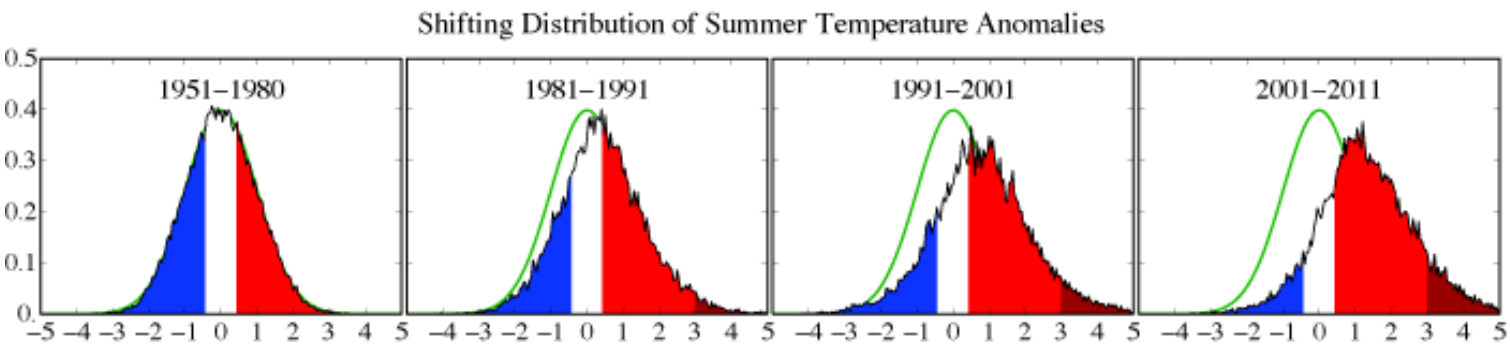


The global thermohaline overturning circulation (from [Rahmstorf, Nature 2002](#))



Extreme temperatures are more common.

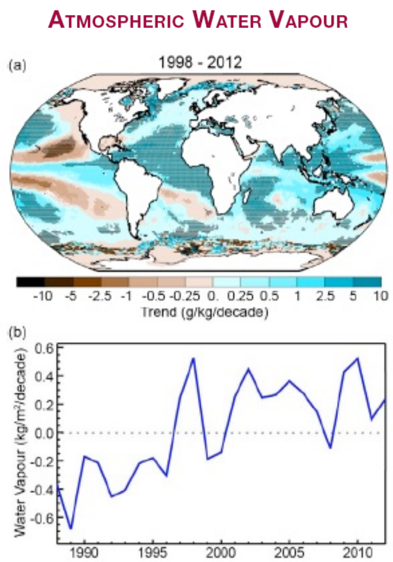
The climate dice are being loaded.

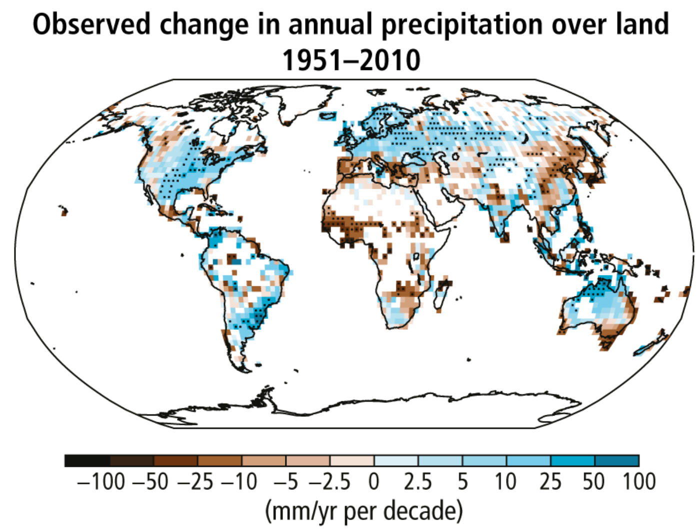


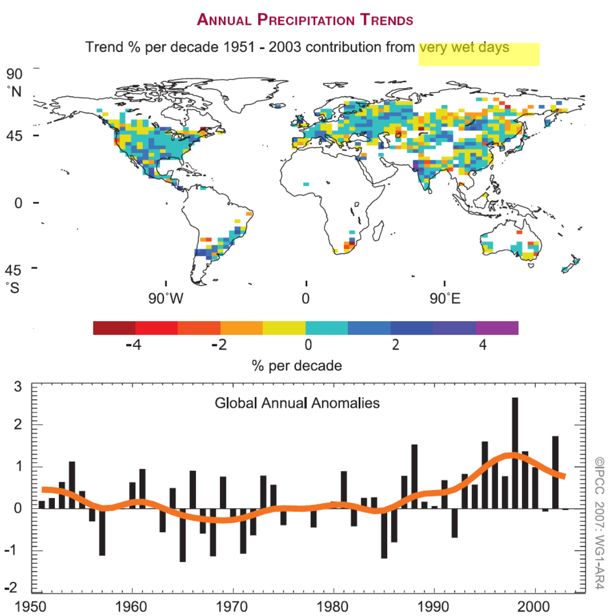
Summer land temps. in the N. Hemisphere

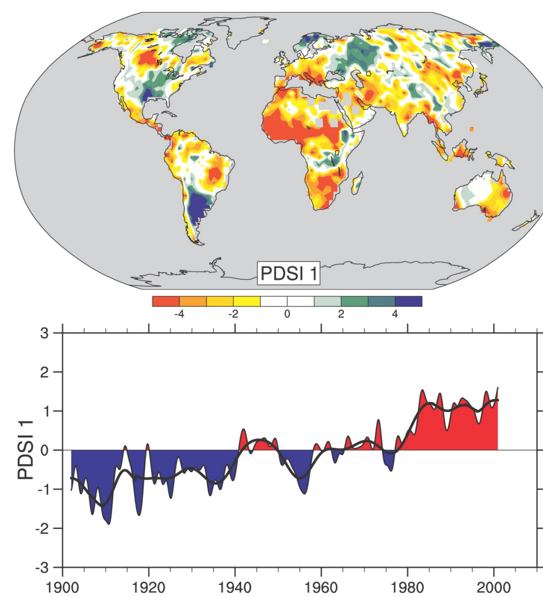
1951-1980	2 sides blue 2 sides white 2 sides red
2001-2011	½ side blue 1 side white 4 sides red ½ side red-brown

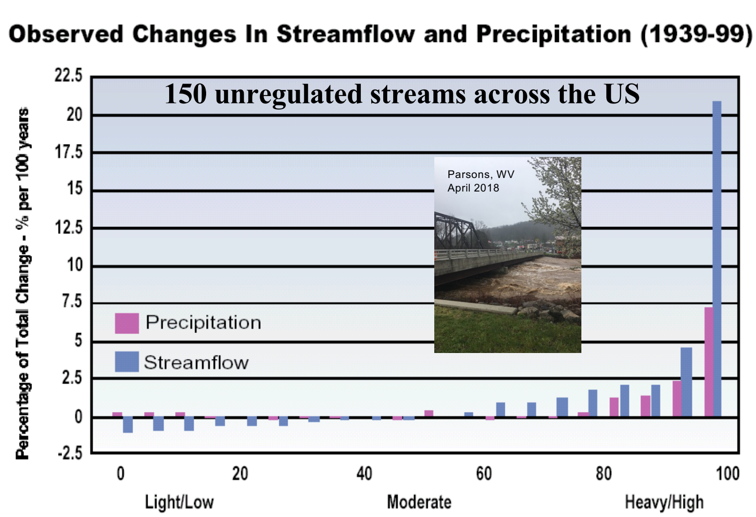
The hydrologic cycle is responding.











Mountain glaciers & snow fields are melting.

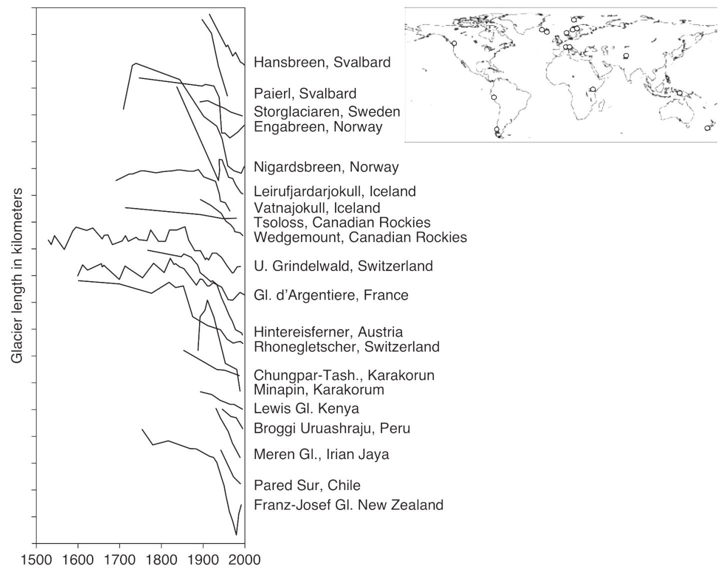
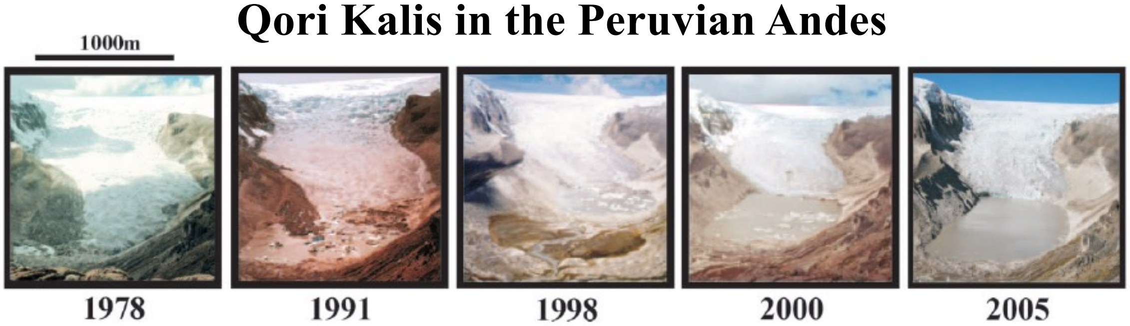
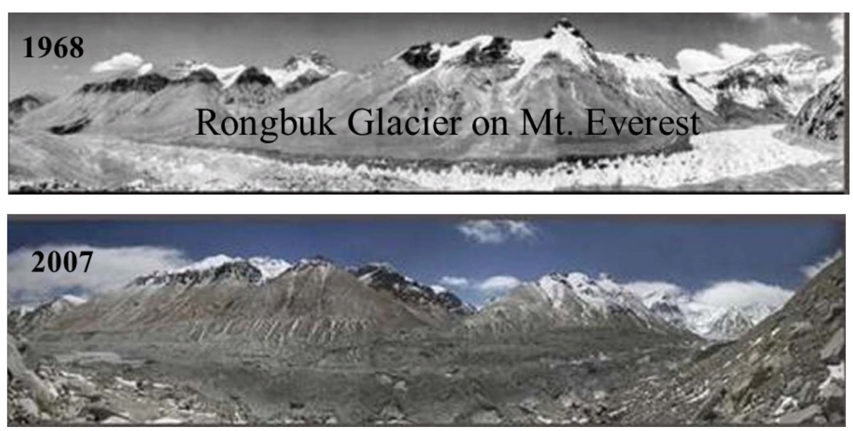


Figure 11-5 Glaciers are melting all over the world. Replotted from the Intergovernmental Panel on Climate Change, 2001.

Qori Kalis in the Peruvian Andes



Glacial Retreat in Glacier National Park

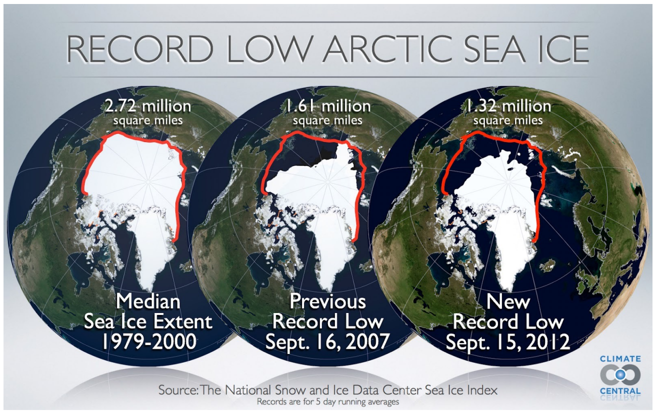


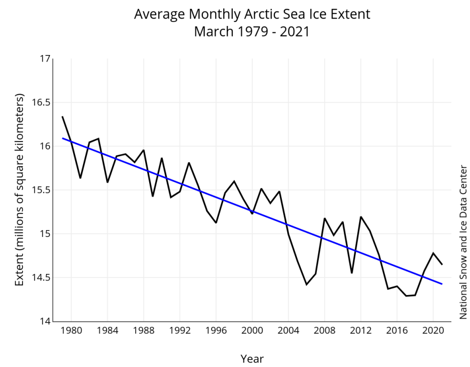
~ 3 billion people rely on water from mountain glaciers & snow packs.

Including:

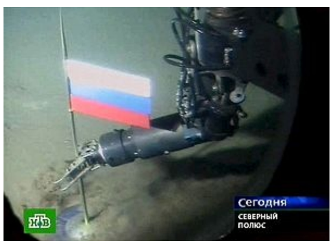
1 billion Chinese, Indians and Bangladeshis
250 million people in Africa
All Californians

Sea ice & large ice sheets are melting.

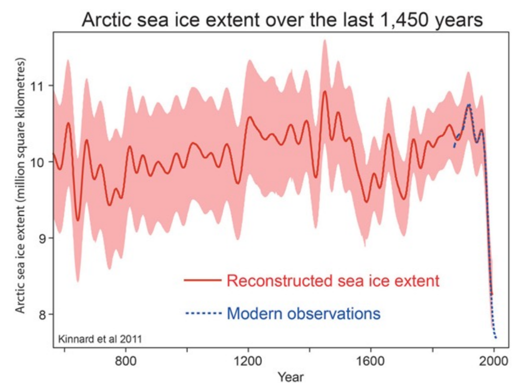


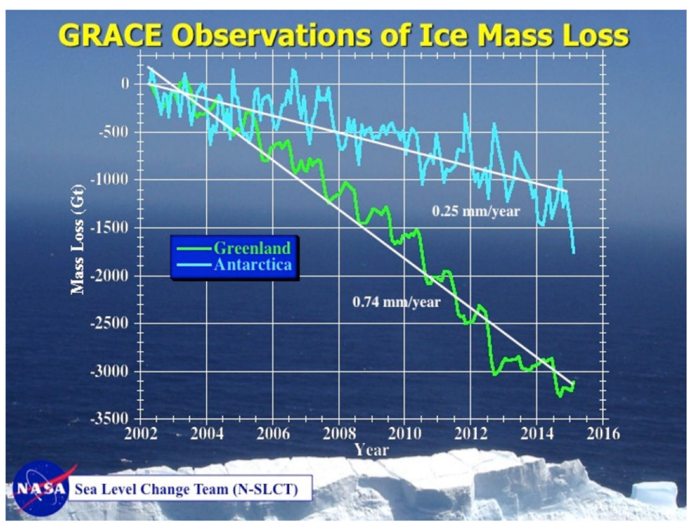


Russia plants flag under North Pole,
claims Arctic energy riches
08/03/2007



Are we getting the message?



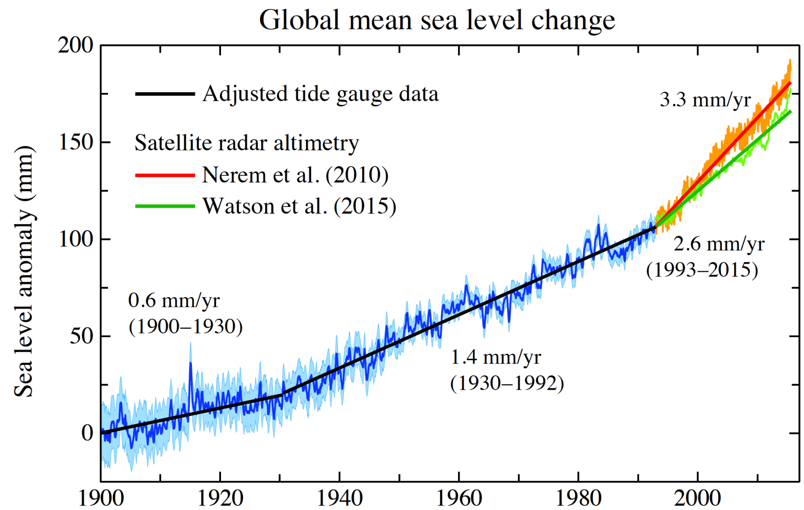


What if it all melted

Mountain glaciers & small ice caps	~35 cm equivalent sea level rise
Greenland	~500 cm
W. Antarctica	~500 cm
E. Antarctica	~7,000 cm
Total	~8,000 cm (80 m or ~240 feet)

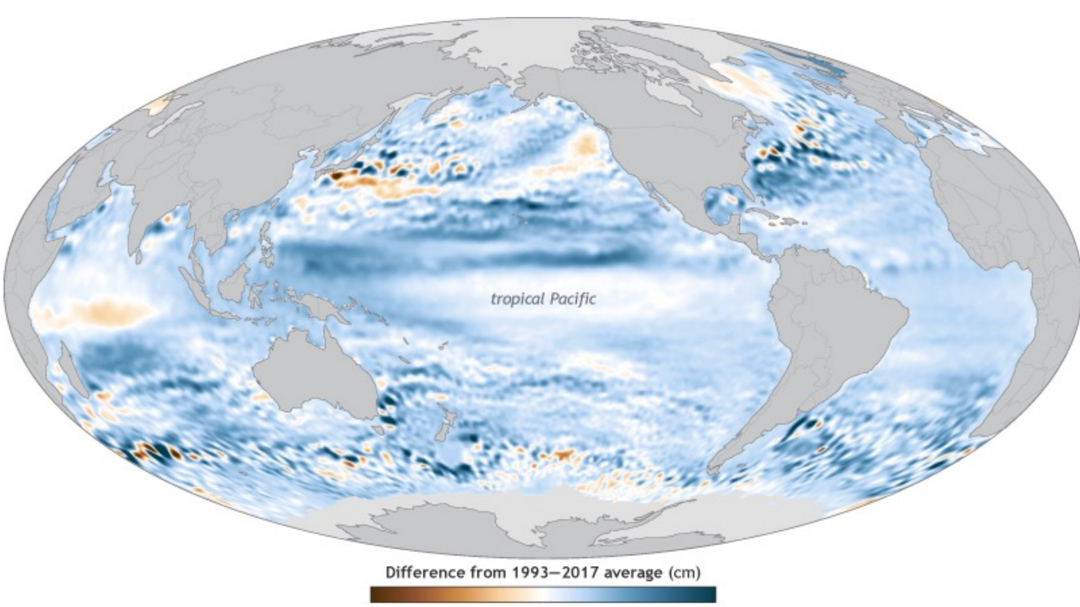
50 cm increase → doubles population @ risk from storm surges
(45 to 90 million)

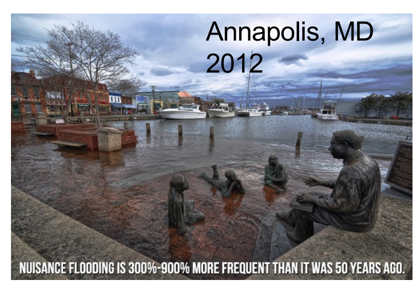
Sea level is rising.



Sources of Sea Level Rise	Sea Level Rise (mm yr^{-1}) 1961–2003 Observed	1961–2003 Modelled	1993–2003 Observed	1993–2003 Modelled
Thermal expansion	0.42 ± 0.12	0.5 ± 0.2	1.6 ± 0.5	1.5 ± 0.7
Glaciers and ice caps	0.50 ± 0.18	0.5 ± 0.2	0.77 ± 0.22	0.7 ± 0.3
Greenland Ice Sheet	0.05 ± 0.12[a]		0.21 ± 0.07[a]	
Antarctic Ice Sheet	0.14 ± 0.41[a]		0.21 ± 0.35[a]	
Sum of individual climate contributions to sea level rise	1.1 ± 0.5	1.2 ± 0.5	2.8 ± 0.7	2.6 ± 0.8
Observed total sea level rise	1.8 ± 0.5 (tide gauges)		3.1 ± 0.7 (satellite altimeter)	
Difference (Observed total minus the sum of observed climate contributions)	0.7 ± 0.7		0.3 ± 1.0	

Notes:
[a] prescribed based upon observations (see Section 9.5)





Sea level rise at specific locations may be more or less than the global average due to local factors: subsidence, upstream flood control, erosion, regional ocean currents, and whether the land is still rebounding from the compressive weight of Ice Age glaciers.

Other living things are responding.

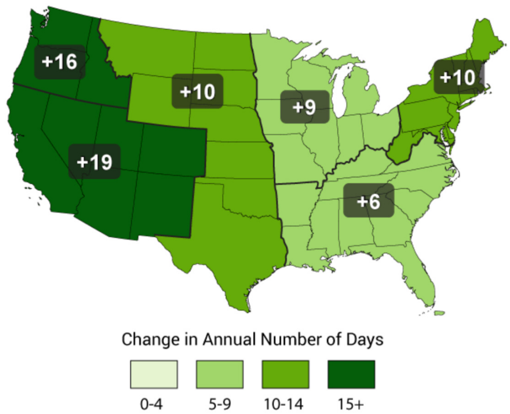
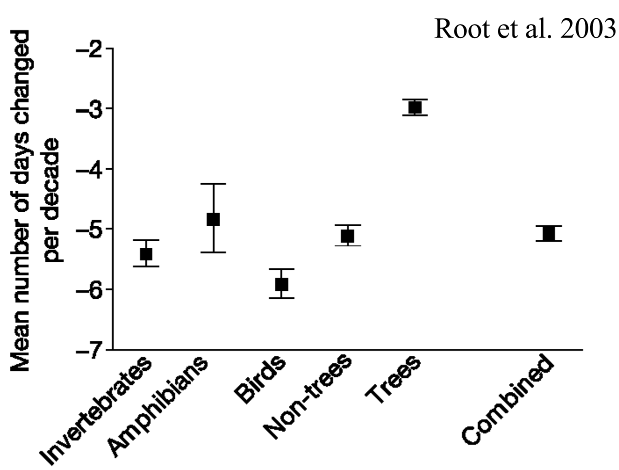
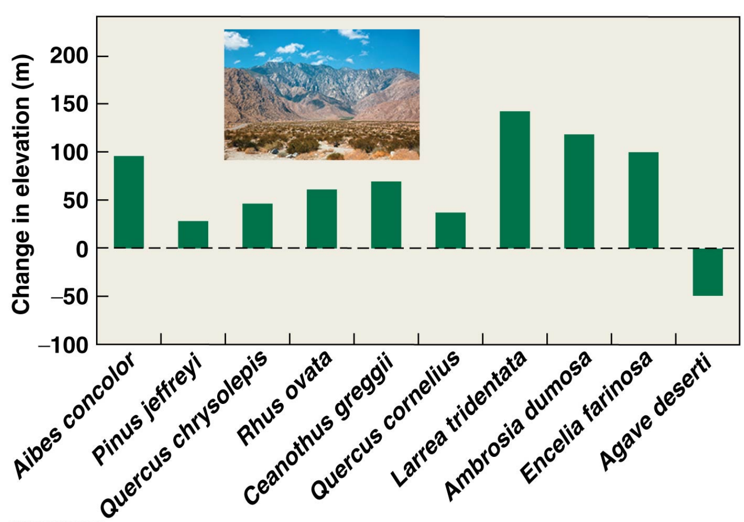


Figure 2.10: The frost-free season length, defined as the period between the last occurrence of 32°F in the spring and the first occurrence of 32°F in the fall, has increased in each U.S. region during 1991-2012 relative to 1901-1960. Increases in frost-free season length correspond to similar increases in growing season length. (Figure source: NOAA NCDC / CICS-NC).

80% of Species Examined (n = 1,468) Show Changes Expected In a Warmer World

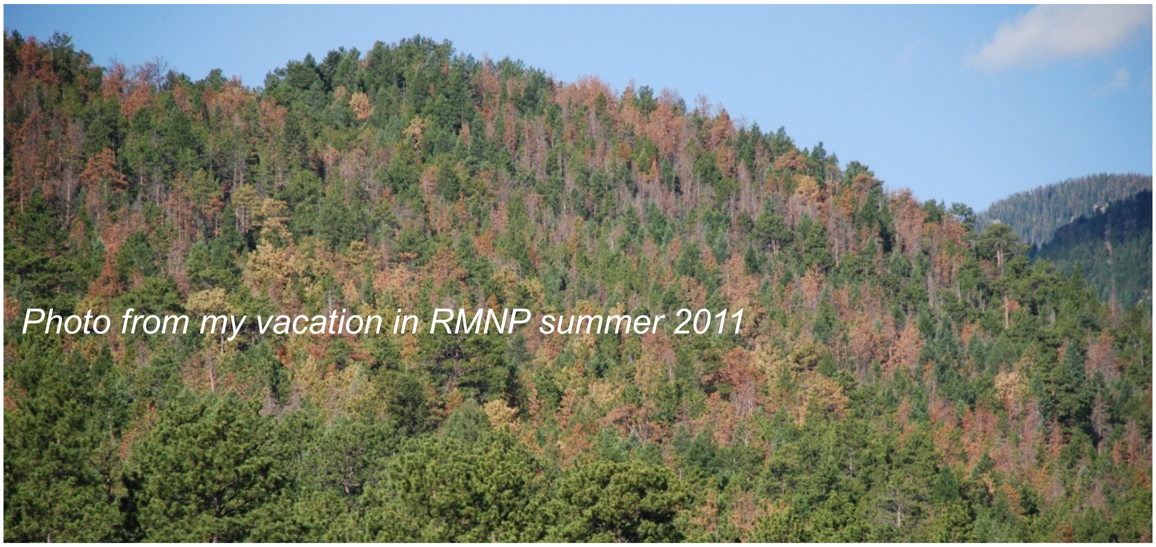


Elevational change in plant species from 1997-2007 in California's Santa Rosa Mountains

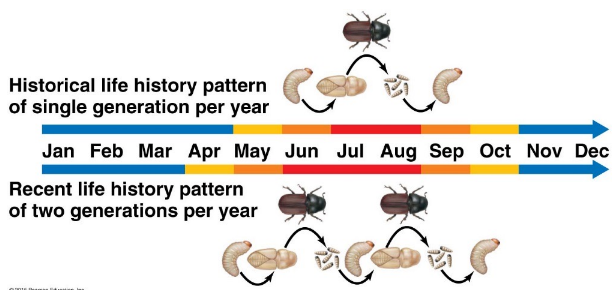


Timing Matters

More destructive bark beetles survive the warmer winters and are moving to higher elevations in the Rocky Mountains



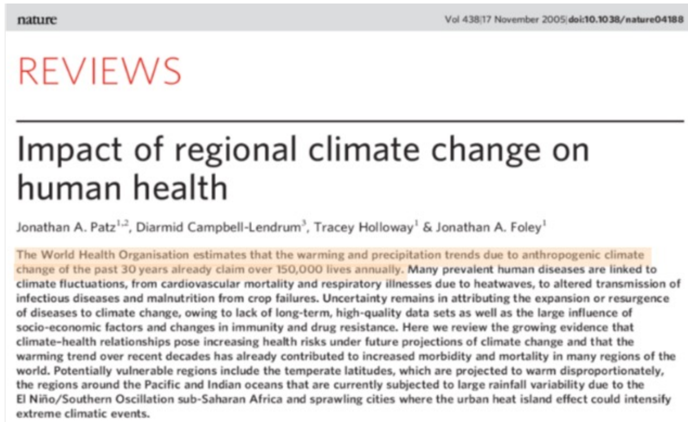
And produce more generations per year.



Cryptic coloration no longer effective

Earlier emergence when food is less available

People are already suffering & dying.

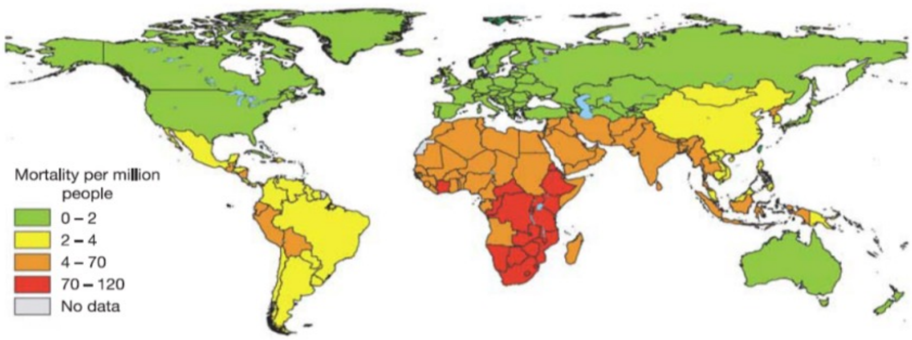

nature Vol 438|17 November 2005|doi:10.1038/nature04188

REVIEWS

Impact of regional climate change on human health

Jonathan A. Patz[1,2], Diarmid Campbell-Lendrum[3], Tracey Holloway[1] & Jonathan A. Foley[1]

The World Health Organisation estimates that the warming and precipitation trends due to anthropogenic climate change of the past 30 years already claim over 150,000 lives annually. Many prevalent human diseases are linked to climate fluctuations, from cardiovascular mortality and respiratory illnesses due to heatwaves, to altered transmission of infectious diseases and malnutrition from crop failures. Uncertainty remains in attributing the expansion or resurgence of diseases to climate change, owing to lack of long-term, high-quality data sets as well as the large influence of socio-economic factors and changes in immunity and drug resistance. Here we review the growing evidence that climate–health relationships pose increasing health risks under future projections of climate change and that the warming trend over recent decades has already contributed to increased morbidity and mortality in many regions of the world. Potentially vulnerable regions include the temperate latitudes, which are projected to warm disproportionately, the regions around the Pacific and Indian oceans that are currently subjected to large rainfall variability due to the El Niño/Southern Oscillation sub-Saharan Africa and sprawling cities where the urban heat island effect could intensify extreme climatic events.



Summer of 2003

CNN.com/WORLD

3,000 dead in French heat wave

Thursday, August 14, 2003 Posted: 12:34 PM EDT (1634 GMT)

Some patients are being treated in hospital corridors in Paris.

Summer of 2010

Voice of America
August 09, 2010

Heat Wave, Smog Double Moscow's Daily Death Rate

James Brooke | Moscow

Russia's summer of heat, drought and fire is starting to take a human toll in Moscow, Europe's most populous city.

Deaths in Moscow have doubled to an average of 700 people a day as the city struggles with a deadly combination of record hot temperatures and poisonous smog from wildfires.

Andre Seltsovky, Moscow's health chief, blamed weeks of heat and smog for the jump in mortality compared to the same time last year.

The average death rate in the city during normal times is between 360-380 people a day, he said. Today, we have around 700.

He added that the city's morgues are filled with 1,300 bodies, close to their capacity. In addition, he said, ambulance trips are up by almost one third, to 10,000 a day. And city officials have ordered 3 million face masks for the population, estimated to be 11 million.

Summer of 2011


CBS DFW
Home News Sports Health Watch + Listen Best Of Weather Traffic Directory Deals Autos
Local Consumer News Politics Business Health Tech Entertainment Texas National World
How Glen Campbell relies on his faith to battle a new challenge. Tonight at 10.

LOCAL

Sweltering North Texas Heat Blamed For Area Deaths

July 20, 2011 5:12 PM

Filed Under: Local, News, Syndicated Local, Watch + Listen, Weather
Related Tags: Extreme Heat, Heat Death, Heat-Related Illness, Heatwave, Texas Drought

Women sit near a fan in a common-room of a rest home. (credit: Johanna Leguerre/AFP/Getty Images)

TARRANT COUNTY (CBSDFW.COM) – The sun and sweltering heat continue to bear down on North Texas.

Wednesday's temperature marked the 19th straight day with temperatures over 100-degrees.

So early into summer, the oppressive heat has already contributed to

Listen LIVE
Sleep Experts
Did you know... The Samaritan Inn is Collin County's ONLY homeless program?
CBS LOCAL Offers – CBS Dallas / Fort Worth
DEAL OF THE DAY 50% off at FoodFriendz.com
CBS DFW VIDEO

November of 2018

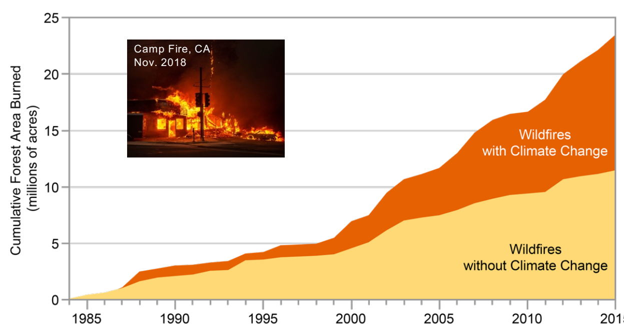
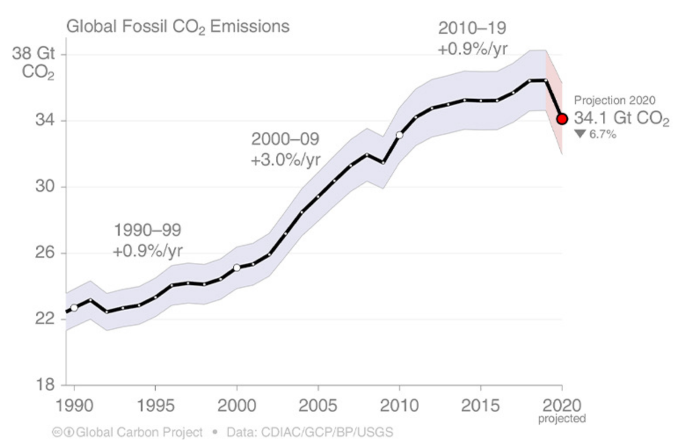
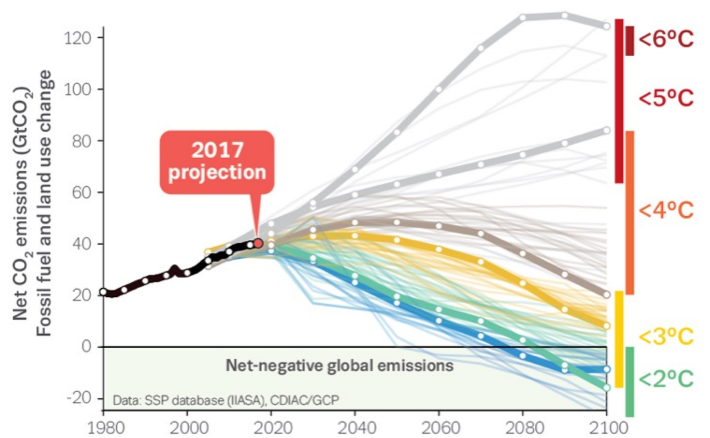


Figure 25.4: The cumulative forest area burned by wildfires has greatly increased between 1984 and 2015, with analyses estimating that the area burned by wildfire across the western United States over that period was twice what would have burned had climate change not occurred. Source: adapted from Abatzoglou and Williams 2016.[7]

If we don’t change our direction, we’ll end up where we’re heading.

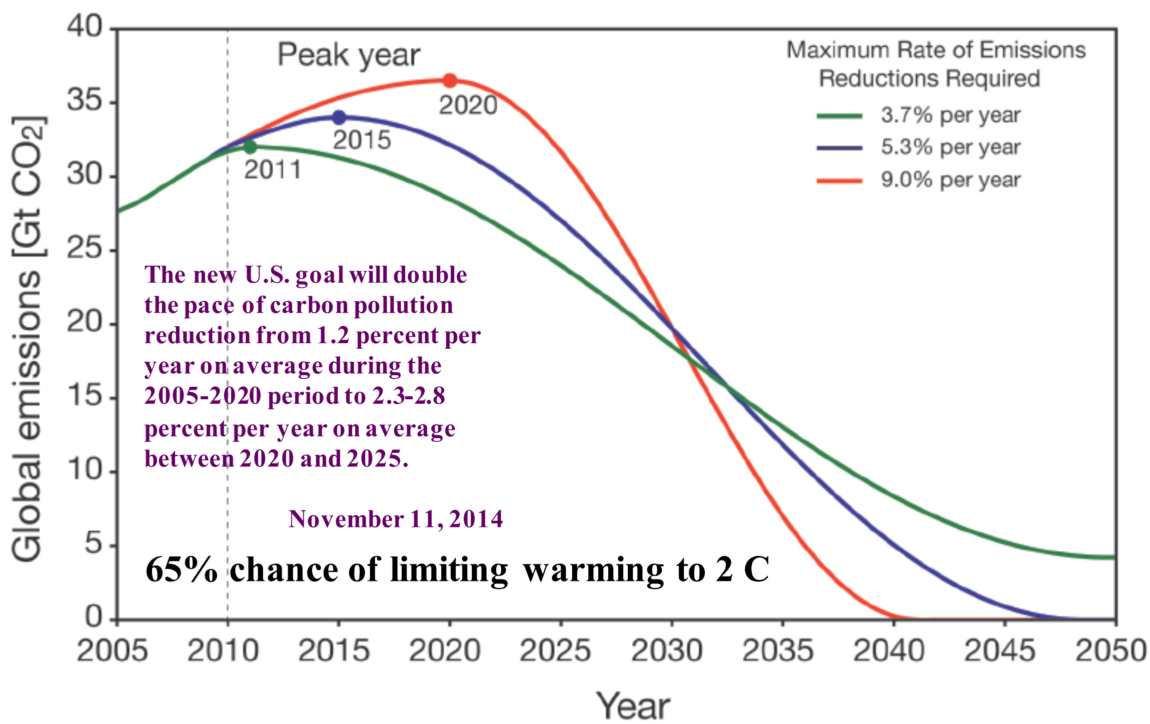




Where should we be heading?

The most widely supported policy goal is to limit global to at most 2 °C above the preindustrial temperature level. But Paris Agreement goal is1.5 ° C

Over the short term this means CO_2 leveling off at 450 ppm

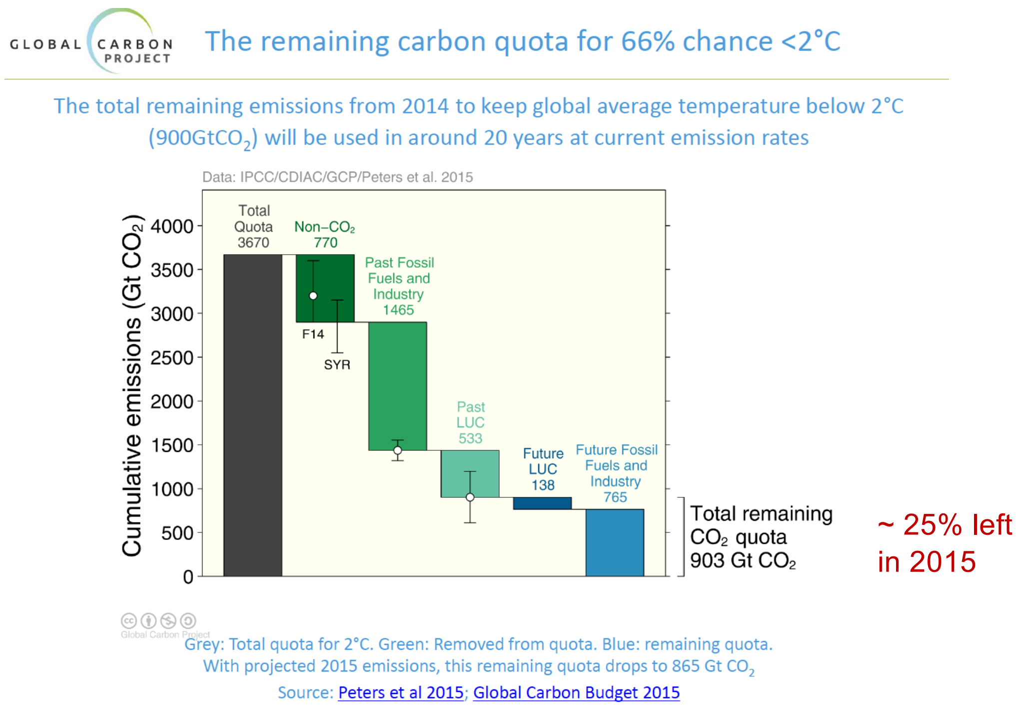


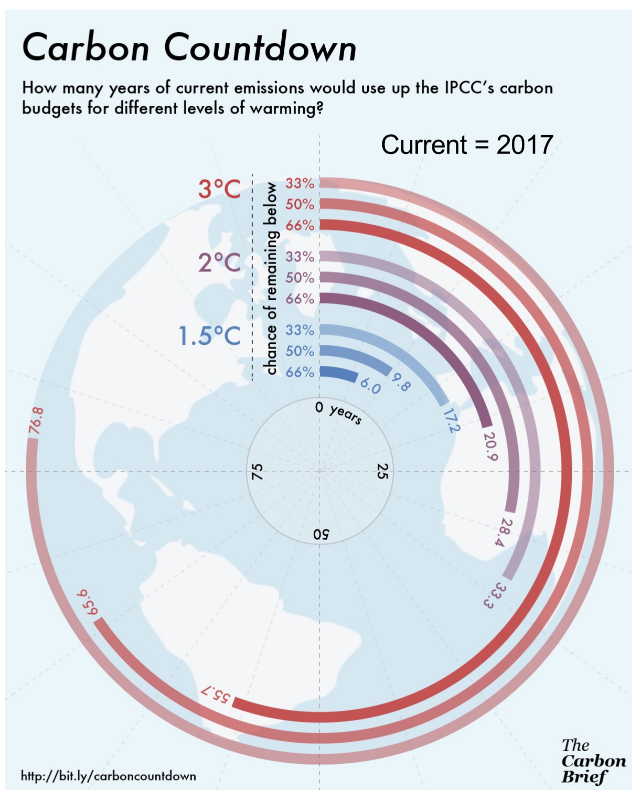
Others disagree

Target CO_2: < 350 ppm

To preserve creation, the planet on which civilization developed

Little time is left to lessen the impacts.





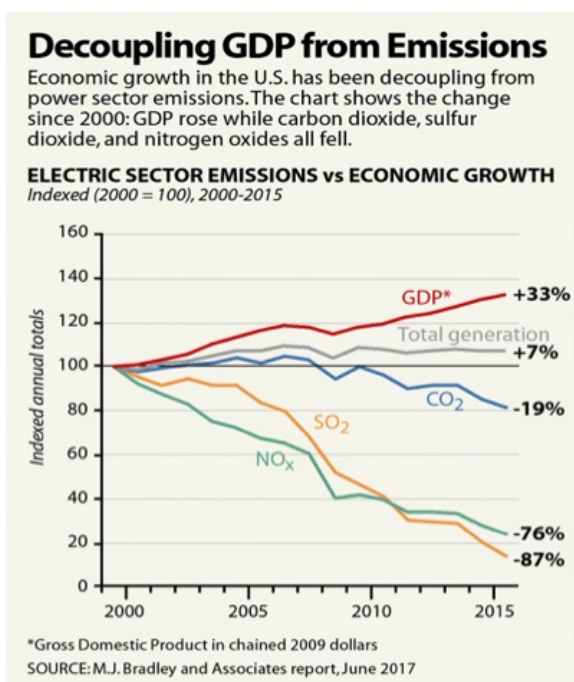
What can one person do?

Don't be one person!
When the ship is sinking, you need all hands on deck.

When you see something, say something.

Realize that these are more than scientific issues.

"... climate change is unjust, a violation of human rights, a sacrilege, and a betrayal of the children. Among other things. And that the crisis offers a chance to reinvent ourselves and our culture in ways that fulfill our potential as human creatures on a life-graced planet". Kathy Dean Moore



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