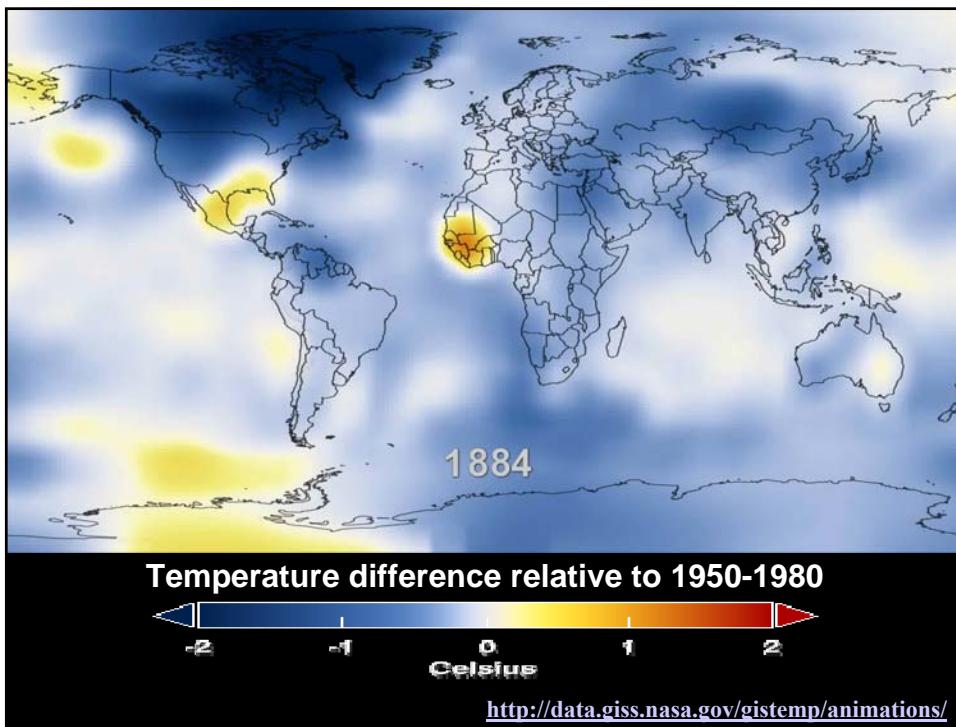
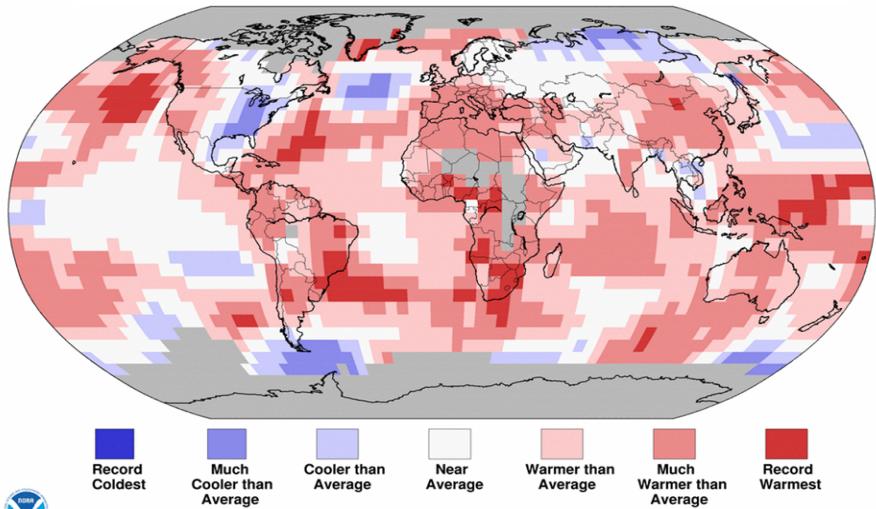


Effects of Climate Change on Agriculture

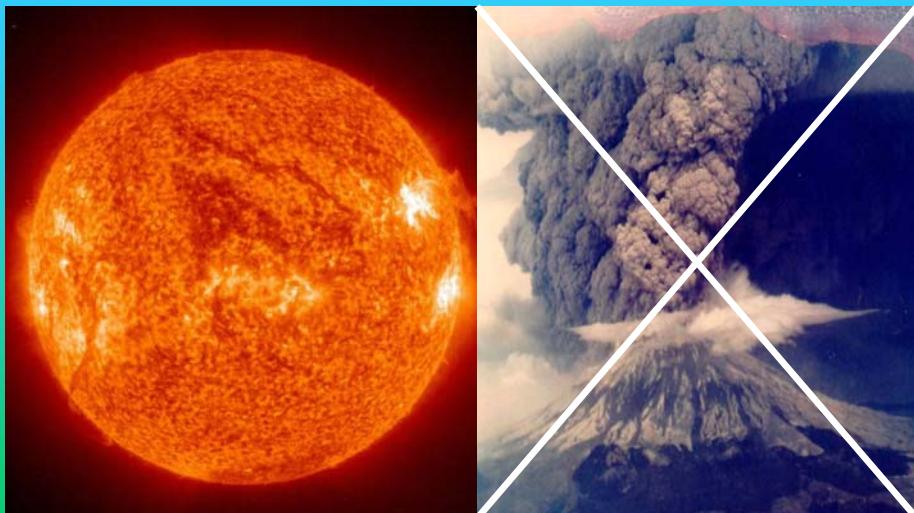


This winter, most of the world was not like Michigan

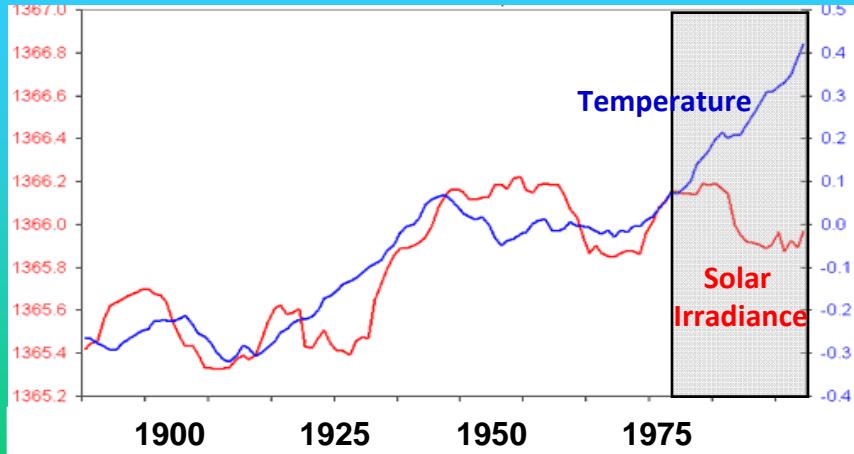
January 2014 Temperatures



“Natural variation” cannot explain current warming



**Recently, while Earth has been warming fastest,
solar irradiance has been decreasing**



**In two major ways, current warming is
very different than any warming period
in at least the last 800,000 years**

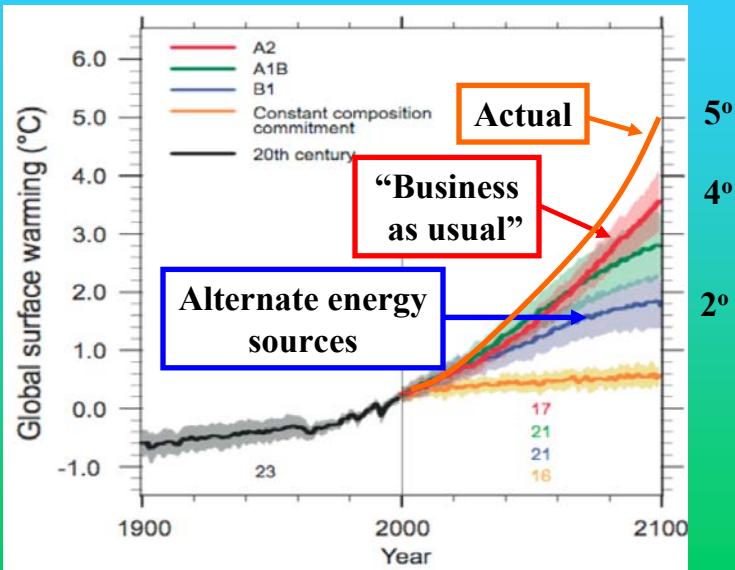
1. It's at least 10-20 times faster
2. It's happening while solar input is decreasing

Best estimate: > 95% of current warming is due to human activities



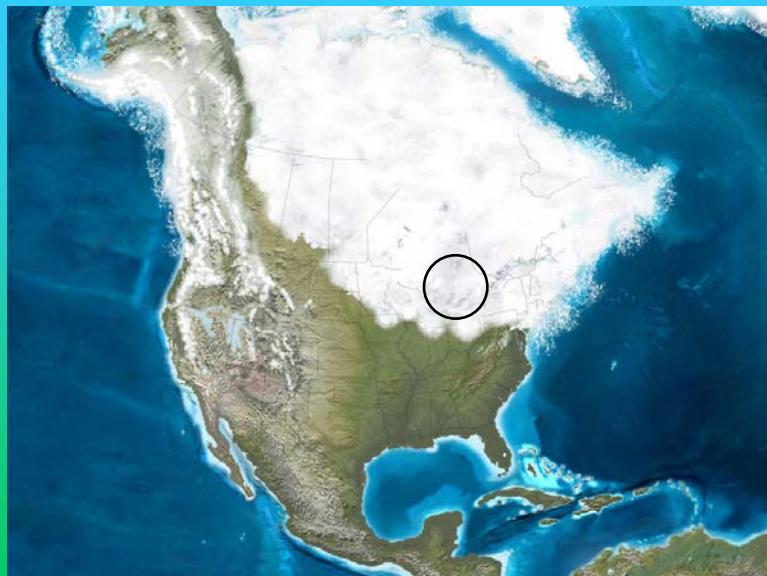
If we remain on our current course, future climate change will be severe

Depending on choices we make, Earth is likely to warm by $2\text{-}5^\circ\text{C}$ by 2100

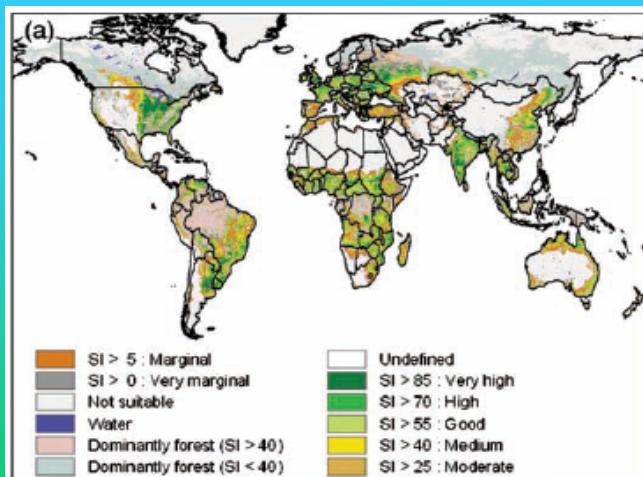


Will a 5° temperature rise matter?

When Earth was 5° cooler:



About 40% of the Earth's surface is used for cropland and pasture



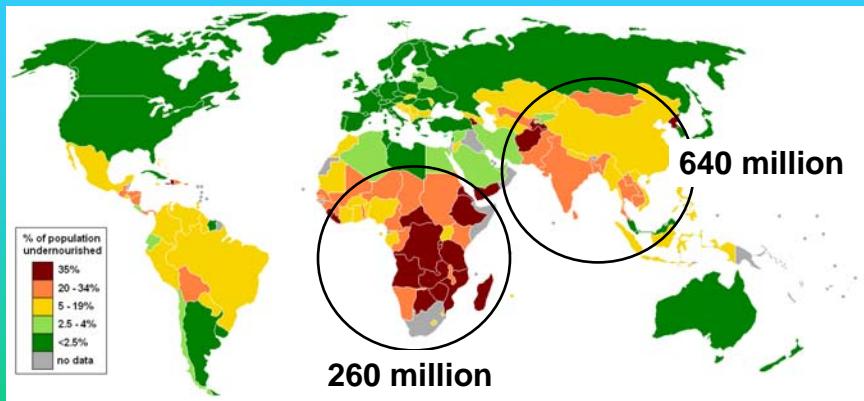
- about 25% of the land surface is too dry for agriculture, and cannot be irrigated

About 450 million of the world's poorest people depend entirely on agriculture



- most widely grown crops are wheat, rice, and corn (maize) ("cereal crops")
- grains provide ~ 2/3 of the total human direct and indirect protein intake

UN Food and Agriculture Organization estimates 1.02 billion hungry people worldwide



- in many developing countries, one third of children under five years old are chronically malnourished

How might climate change affect agriculture?

Increased yields due to:

- 1. CO₂ fertilization effect**
- 2. Longer growing season**

Decreased yields due to:

- 3. Increased temperatures**
- 4. Increased droughts**
- 5. Increased flooding**
- 6. Decreased nutritional quality**
- 7. Decreased water for irrigation**
- 8. Increased pests**

CO₂ fertilization effect: when grown under higher CO₂, most crop plants grow bigger and produce higher yields

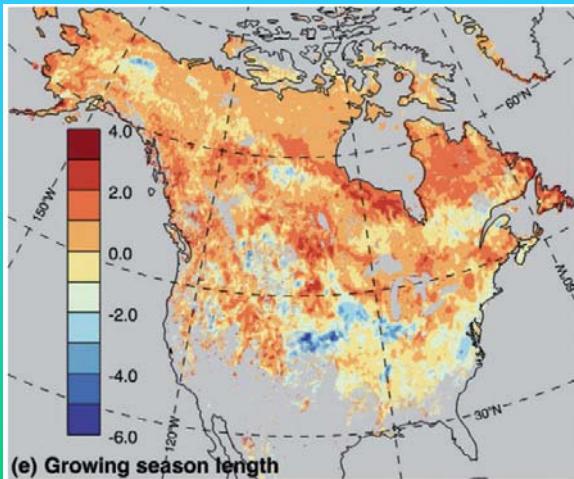
- bigger effect for soybean, rice, and wheat



than for corn



Climate change has already increased growing season at higher latitudes



- but reduced it a bit at lower latitudes

Despite longer growing season, climate change has decreased global yields of wheat and corn since 1960



- no effect observed yet for soybean or rice



How might climate change affect agriculture?

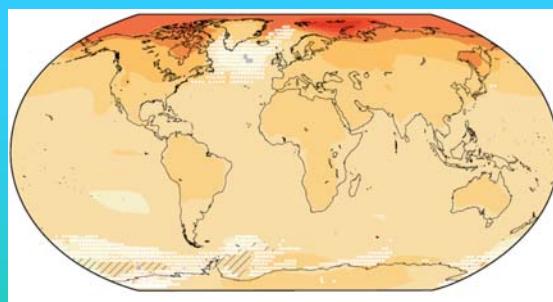
Increased yields due to:

1. CO₂ fertilization effect
2. Longer growing season

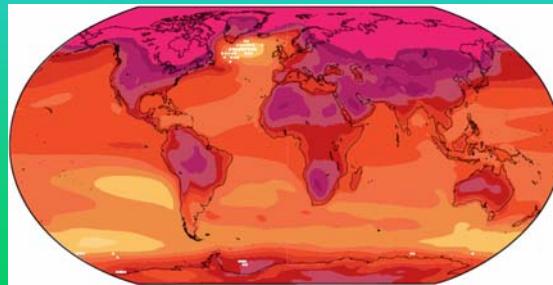
Decreased yields due to:

3. Increased temperatures
4. Increased droughts
5. Increased flooding
6. Decreased nutritional quality
7. Decreased water for irrigation
8. Increased pests

Future warming depends on greenhouse gas emissions

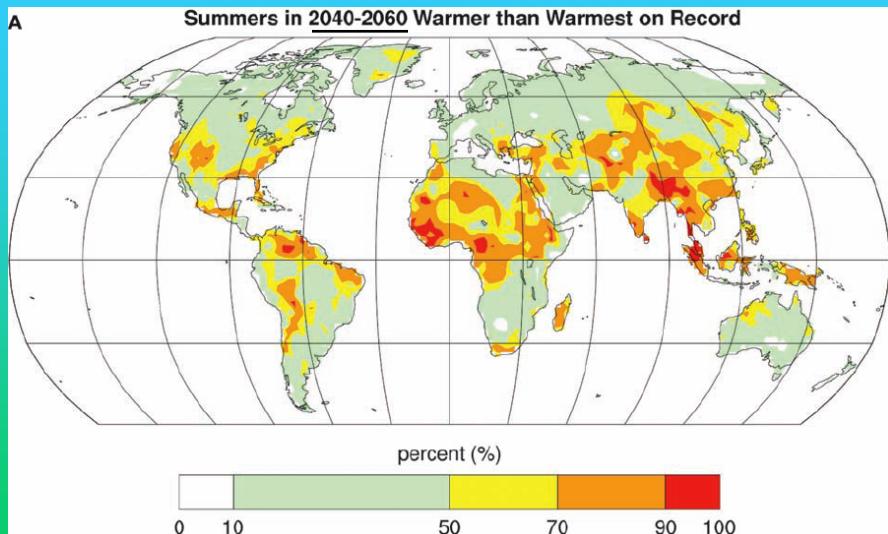


Lower Emissions

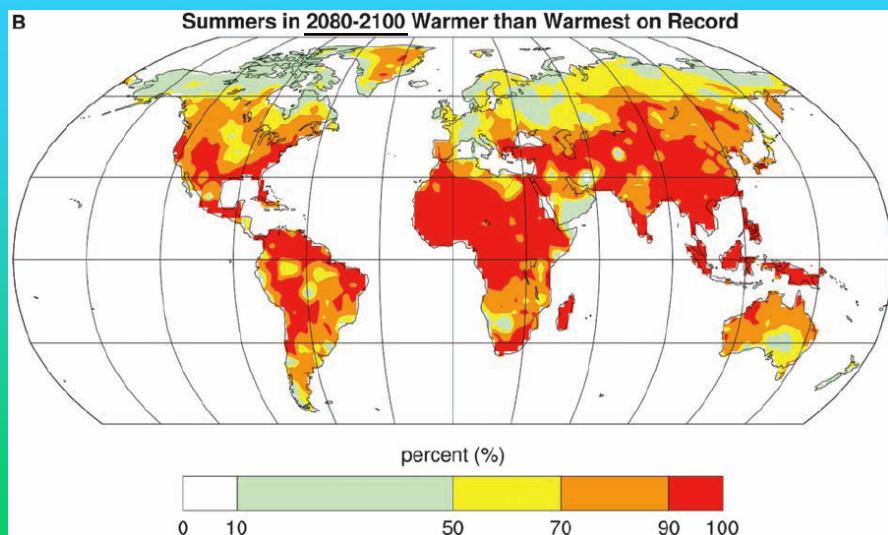


Higher Emissions

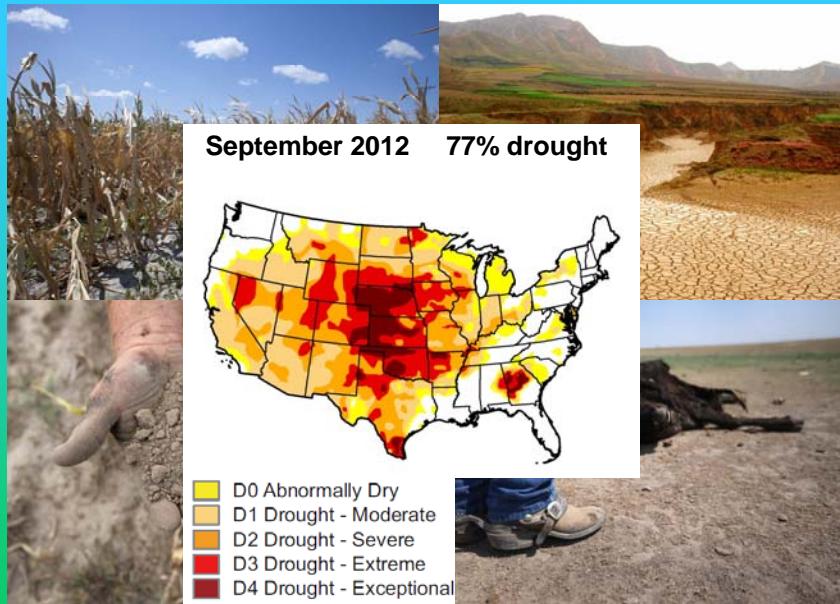
Most summers are likely to be hotter than any experienced thus far



Most summers are likely to be hotter than any experienced thus far



Much of the U.S. has been experiencing severe drought



Agricultural damage was tens of billions of dollars

U.S. crop losses in the summer of 2012:



Corn 50%



Sorghum 50%



Soybeans 35%



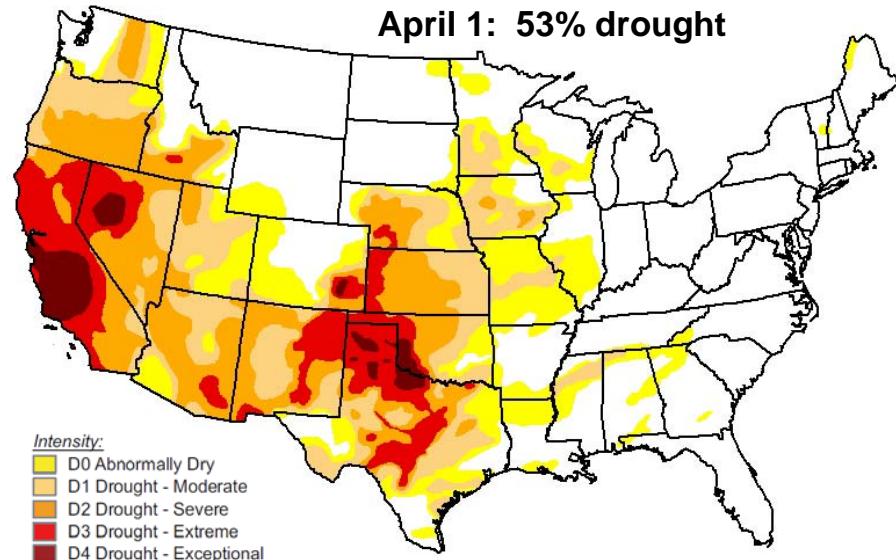
Cotton 30%



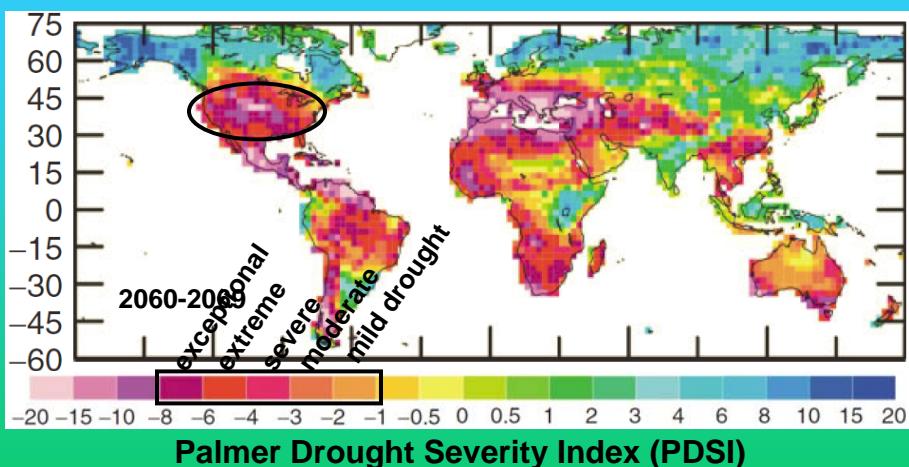
Pastures and rangeland 55%

Is the U.S. still in drought?

April 1: 53% drought



Much of the world is likely to experience much more frequent and stronger droughts by the 2060s



- current drought indices will longer be sufficient

Severe rainstorms have already become more common



40% increase in southwest Michigan since 1948

Flooding is also likely to reduce future yields

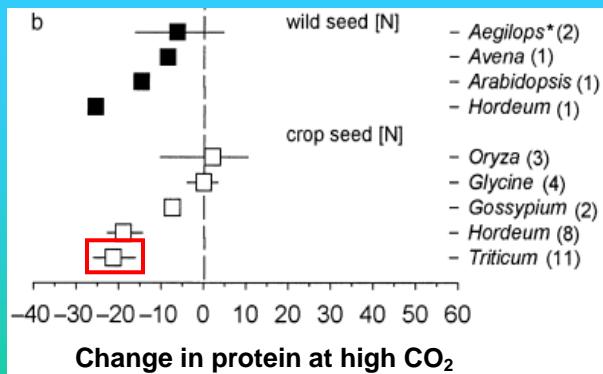


- in US Midwest, the probability of a flood event that destroys $\geq 20\%$ of yield is predicted to double by 2030 and quadruple by 2090

CO₂ fertilization includes a second effect

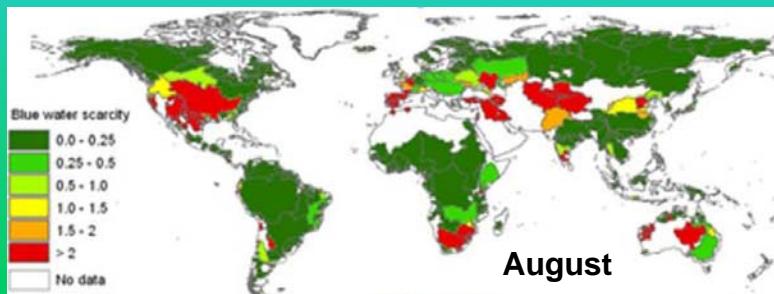
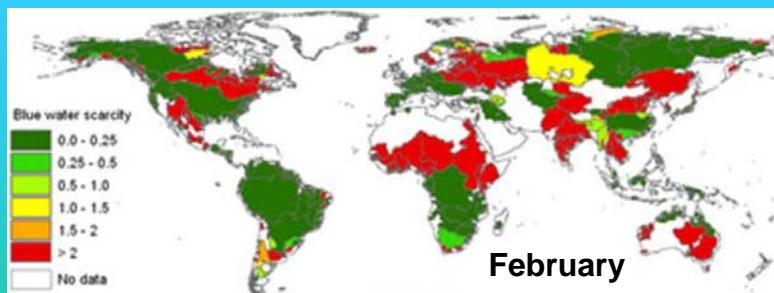


- wheat protein decreases by 20%



- so any increase in quantity may be offset by a decrease in quality

Half of Earth's 400 major river basins already experience at least a month of water scarcity

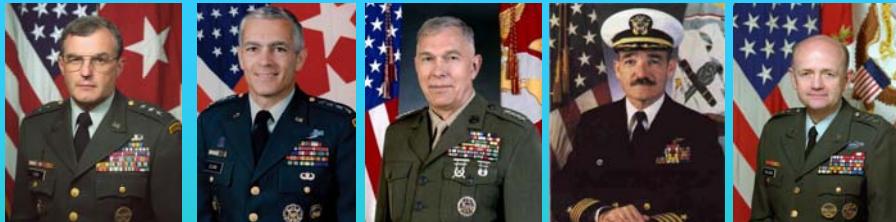


Water scarcity is a U.S. national security threat



- Indus River supplies 83% of Pakistan's irrigation water

- might India and Pakistan start a “water war”?



“The effects of climate change in the world’s most vulnerable regions present a serious threat to American national security interests. Washington must lead on this issue now.”

Partnership for a Secure America, February 2013

Crop pests are likely to increase with warming



To some extent, adaptation measures can mitigate the adverse effects of climate change



irrigation



planting dates

- others include crop selection, pest control, planting and harvesting technology, and genetic engineering of crops

How will crops attain drought resistance?

Most predictions of future yields include:

CO₂ fertilization effect (larger size)

Longer growing season

Increased temperature

Altered precipitation

But do not include:

Increased droughts

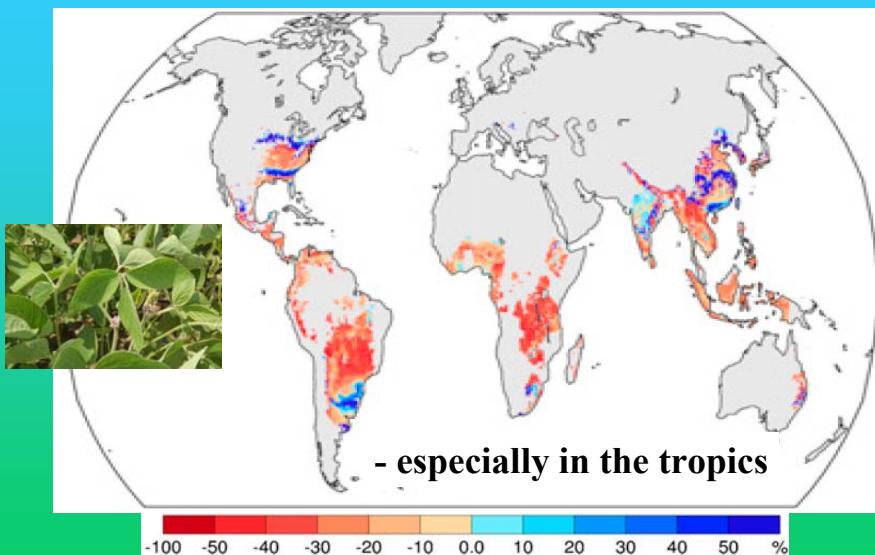
Increased flooding

CO₂ fertilization effect (nutritional quality)

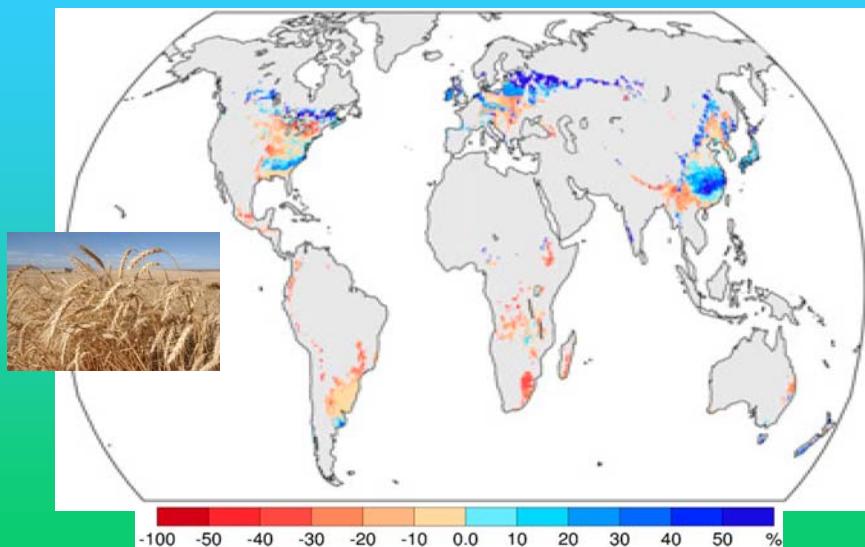
Decreased water for irrigation

Increased pests

By 2050, climate change is likely to decrease global yield of soybean

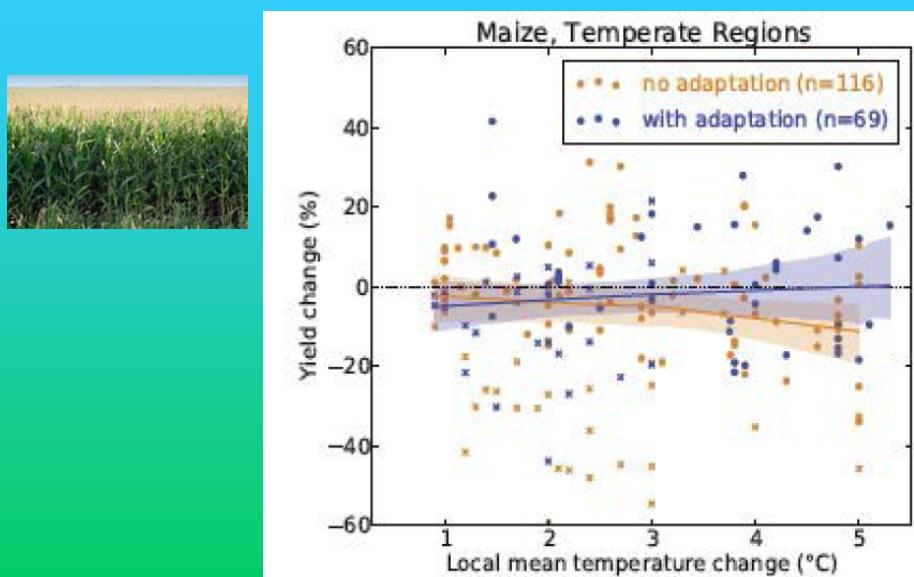


By 2050, climate change is likely to have little overall effect on global yield of wheat



- more likely to decrease in the tropics

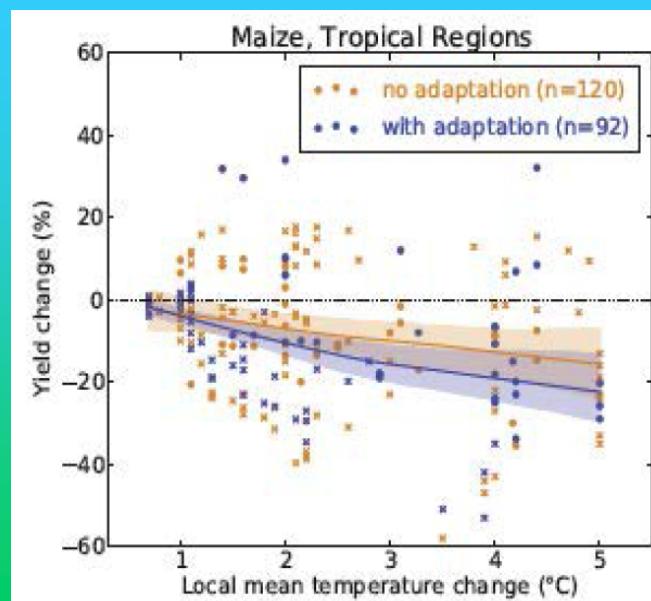
Climate change may have little effect on yield of corn in temperate latitudes



But a moderate negative effect on yield of corn in tropical latitudes



~ 15% decrease with 5° rise



Several recent studies the include more variables are much more pessimistic about future yields

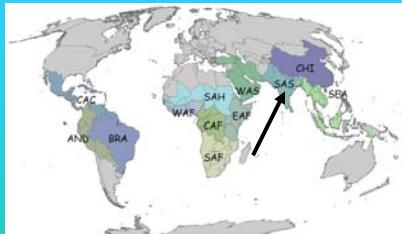
- future U.S. corn and soybean yields may decrease dramatically



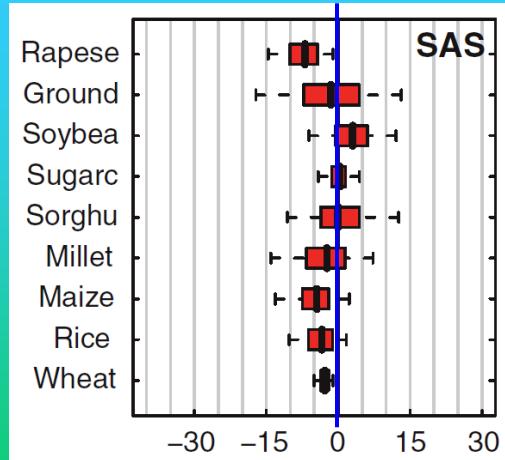
20-25% decrease by 2050

55-60% decrease by 2100

By 2030, most of the important crops in India and Pakistan are predicted to have reduced yields



- 30% of world's
malnourished people



Developed countries are causing the problem, but developing countries experience most health costs

Countries proportional to CO₂ emissions (1950-2002)



Countries proportional to climate-sensitive health effects



What can I do to minimize climate change?



We can change the future by implementing multiple solutions that already are available

Weatherize your house: weather-strip, adequately insulate attic, and replace single-pane windows with triple-pane windows



Next time, buy a more fuel-efficient car

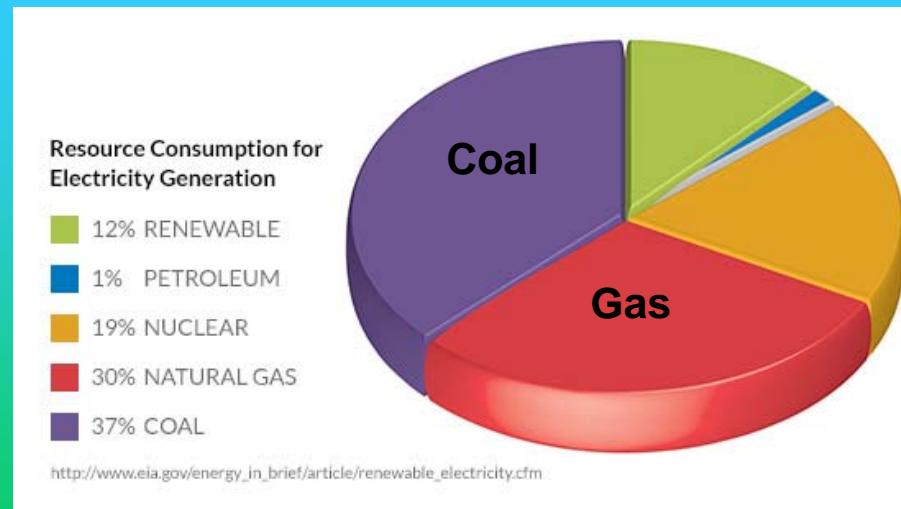


Unfortunately, energy conservation is not a solution



- really just delays the outcome

**67% of U.S. electricity is generated
by burning coal or gas**



**To limit warming to 2° C, we need to reduce
greenhouse gas emissions by 80% by 2050**

**This can only happen through aggressive expansion
of alternate energy sources**



Solar



Wind

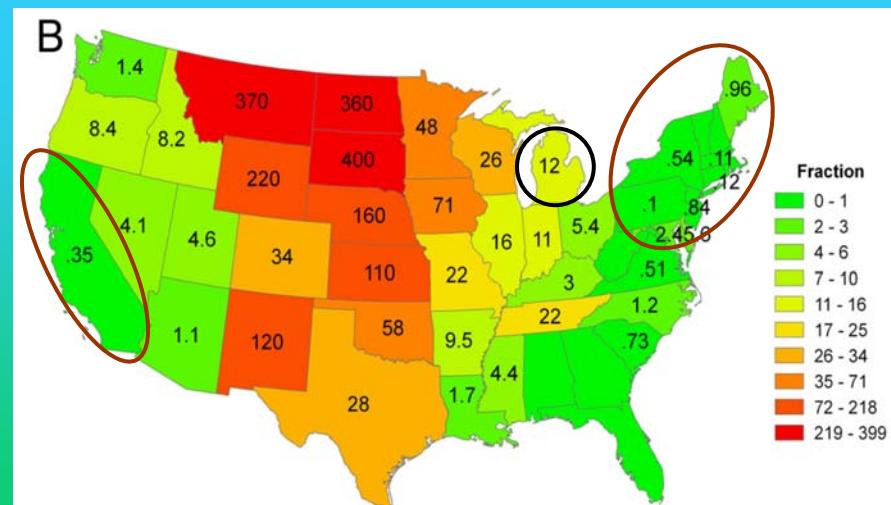
**Globally, we generate only 0.2% of our energy from wind,
and only 0.1% from solar**

Global wind potential is >40 times worldwide use

All 9 highest CO₂-emitting countries could use wind alone



Wind power in Michigan could supply 12 times current statewide electricity demand



The “intermittency problem” can be solved easily

e.g. Luddington pumped storage plant



Solar energy has even greater potential

**More energy reaches Earth
from the sun in 1 hour than
humans on the entire
planet use in 1 year!**



Three main solar electricity technologies:



solar tower



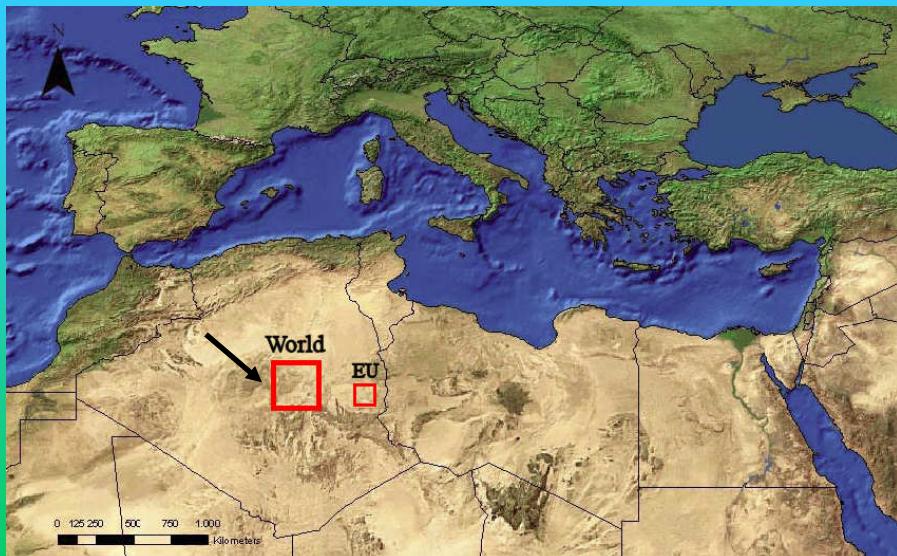
parabolic trough



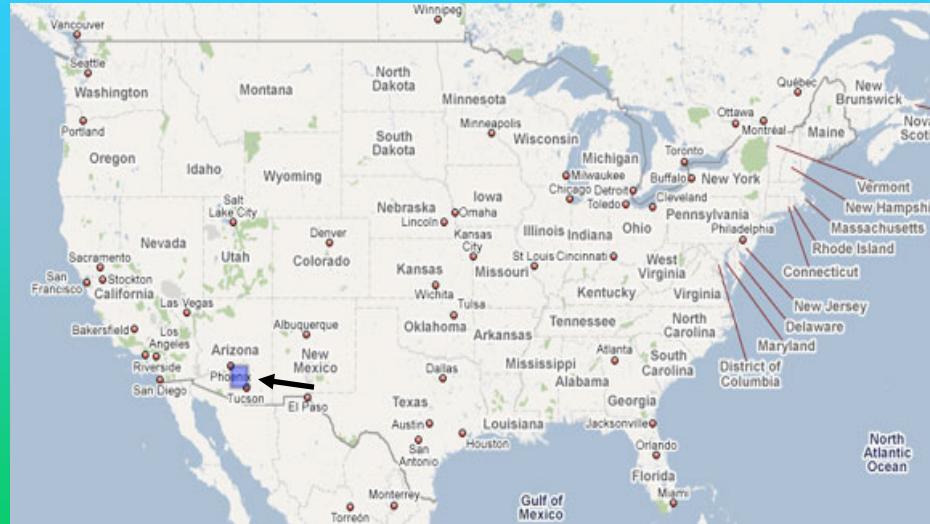
photovoltaics

Global potential estimated at up to 100 times current use

A small portion of the Sahara desert could supply all of the world's electricity



A solar array 100 x 100 miles could provide all of US energy needs today



Again, “intermittency problem” can be solved easily



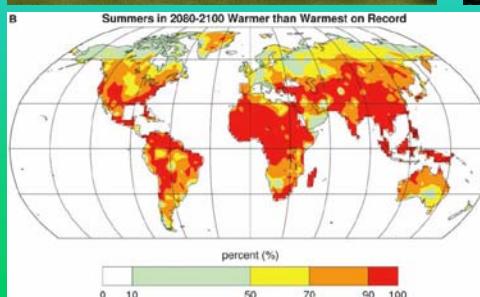
solar tower



parabolic trough

- store excess heat during day, generate electricity at night

Sooo... we're not doing it now because the cost is much higher than electricity from coal, right?



The true costs of wind and solar are already lower than coal-generated electricity

True cost per kilowatt hour of power

Coal:	26¢
Offshore wind:	3¢
Onshore wind:	6¢
Solar troughs:	11¢
Solar towers:	20¢
Solar PV:	40¢

Educate others

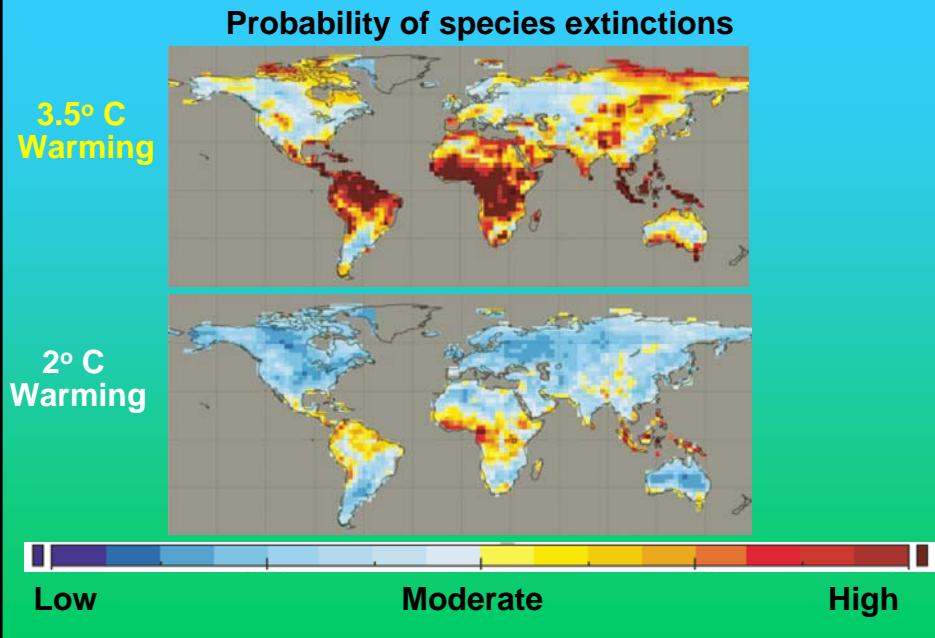


Encourage policymakers to make smarter choices



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What would we gain by making these smarter choices?



Worst case scenario:



The future is in your hands

