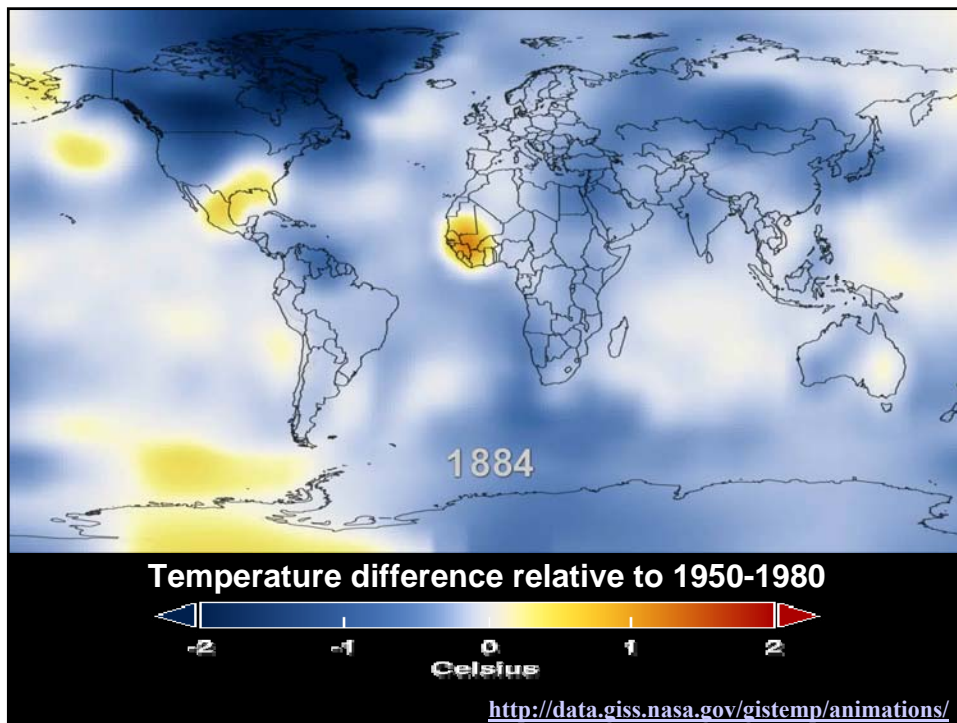
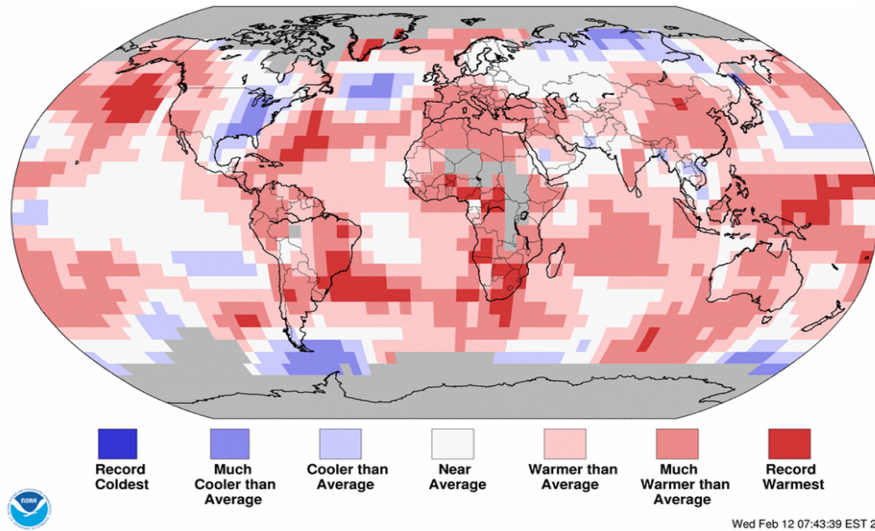


## Effects of Climate Change on Agriculture

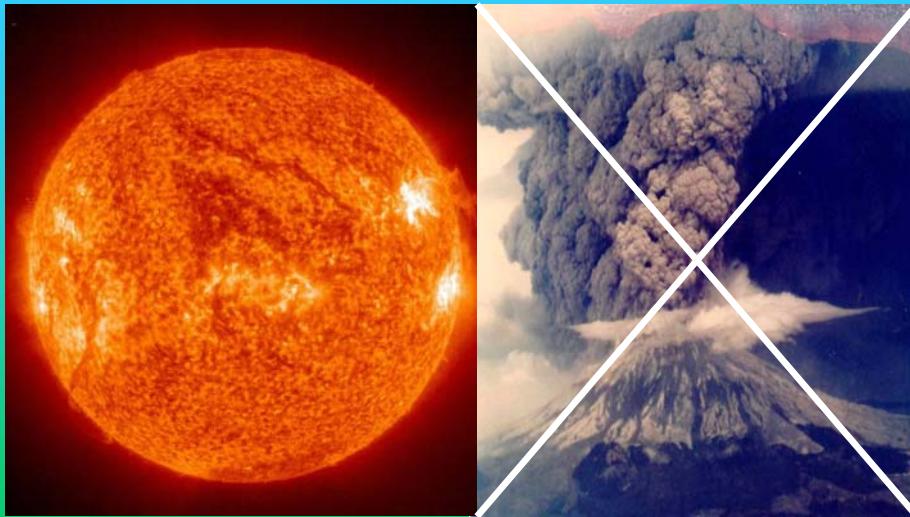


**This winter, most of the world was not like Michigan**

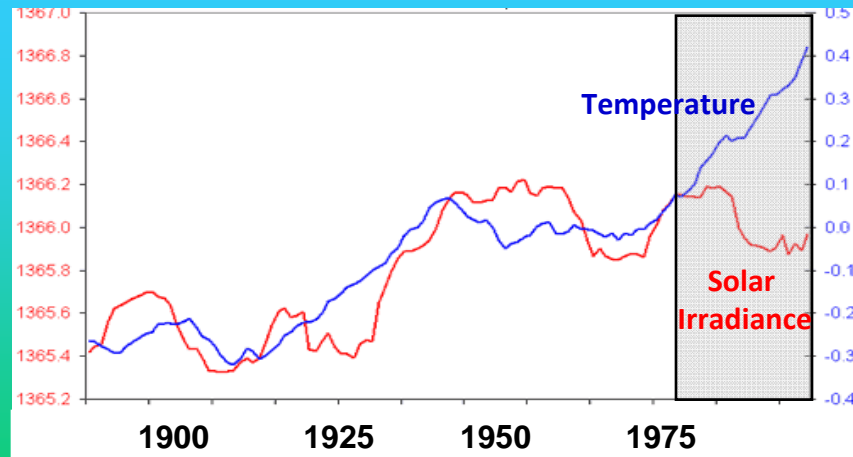
**January 2014 Temperatures**



**“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**

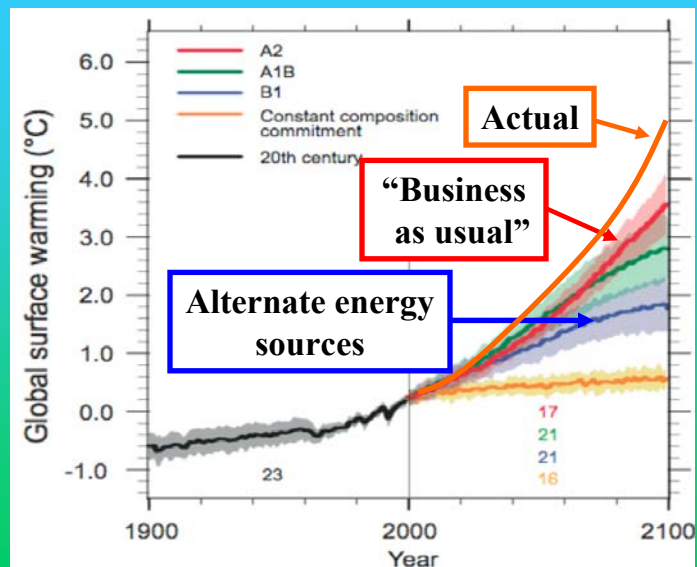
- 1. It's at least 10-20 times faster**
- 2. It's happening while solar input is decreasing**

**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  
2-5° C  
by 2100



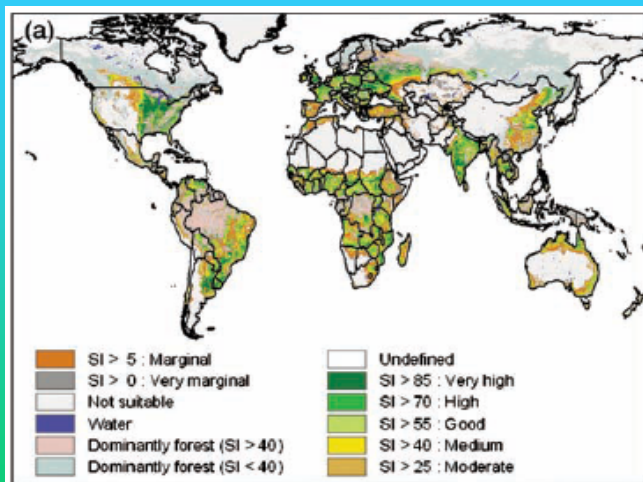


**Will a 5° temperature rise matter?**

**When Earth was 5° cooler:**



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



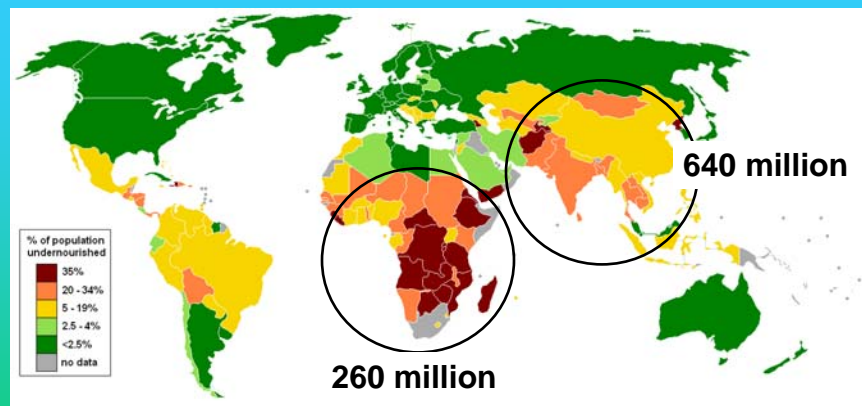
**- about 25% of the land surface is too dry for agriculture, and cannot be irrigated**

**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. CO<sub>2</sub> 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**

**CO<sub>2</sub> fertilization effect: when grown under higher CO<sub>2</sub>, most crop plants grow bigger and produce higher yields**

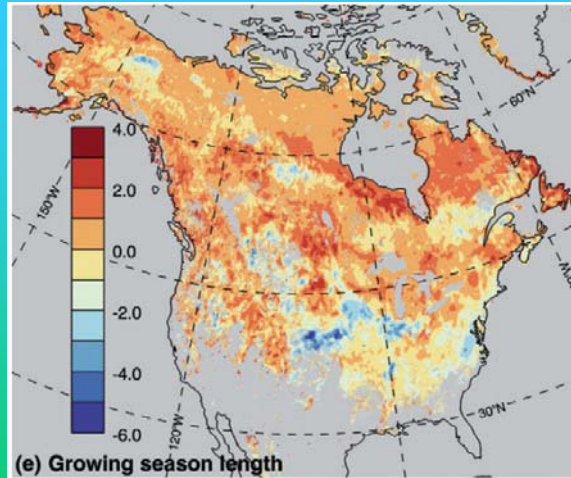
**- bigger effect for soybean, rice, and wheat**



**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?

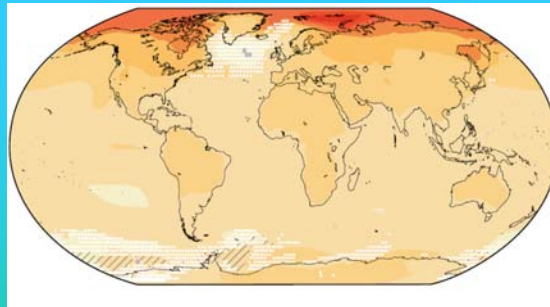
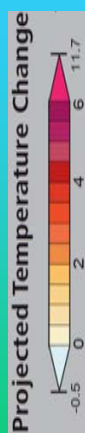
### Increased yields due to:

1. CO<sub>2</sub> fertilization effect
2. Longer growing season

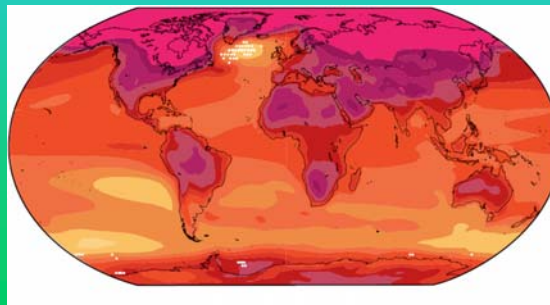
### Decreased yields due to:

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

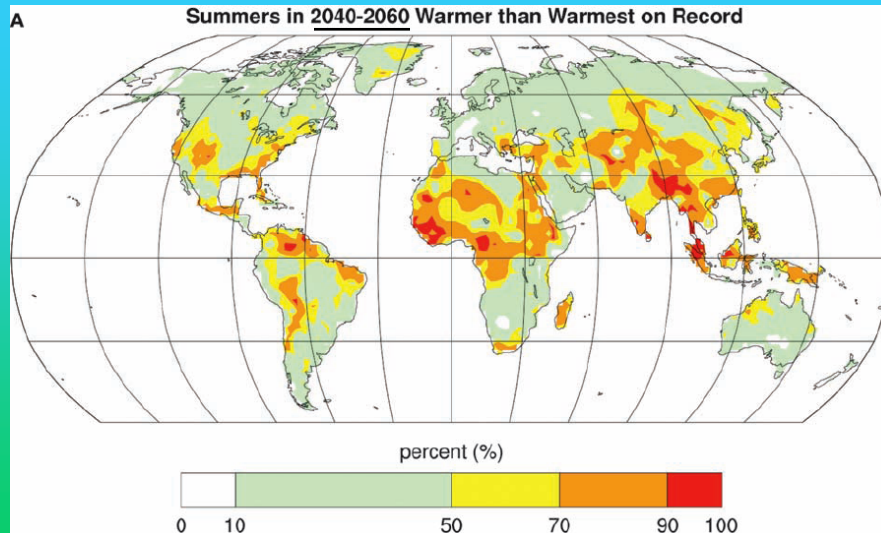


**Lower  
Emissions**

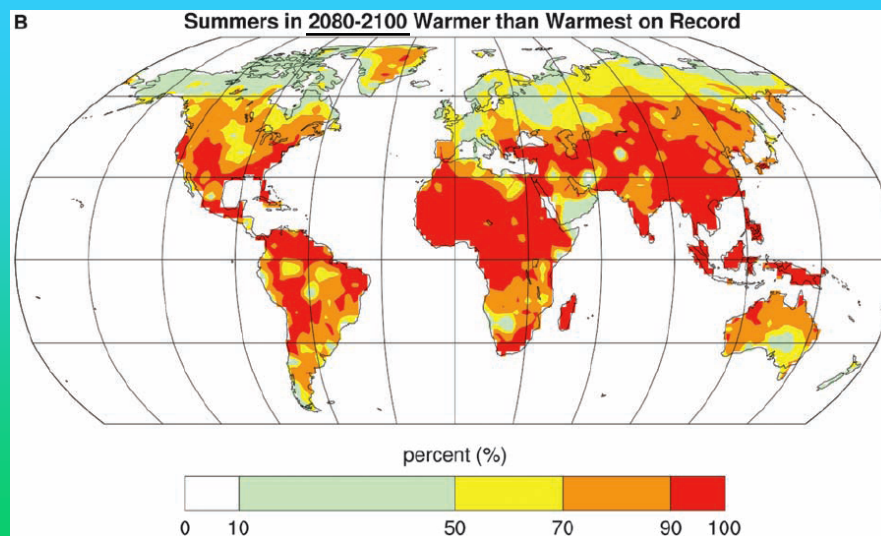


**Higher  
Emissions**

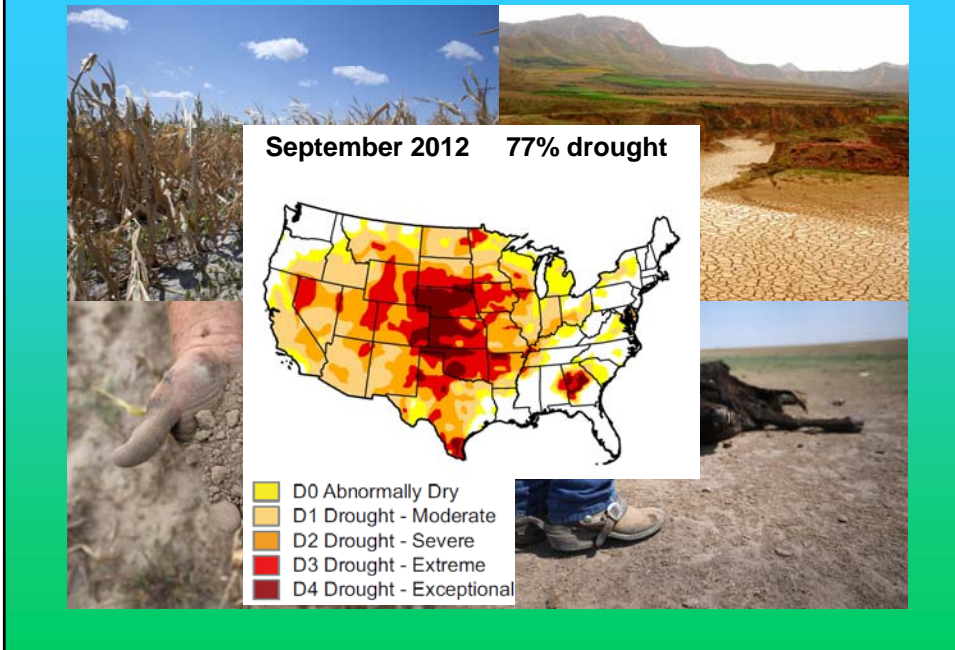
## Most summers are likely to be hotter than any experienced thus far



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

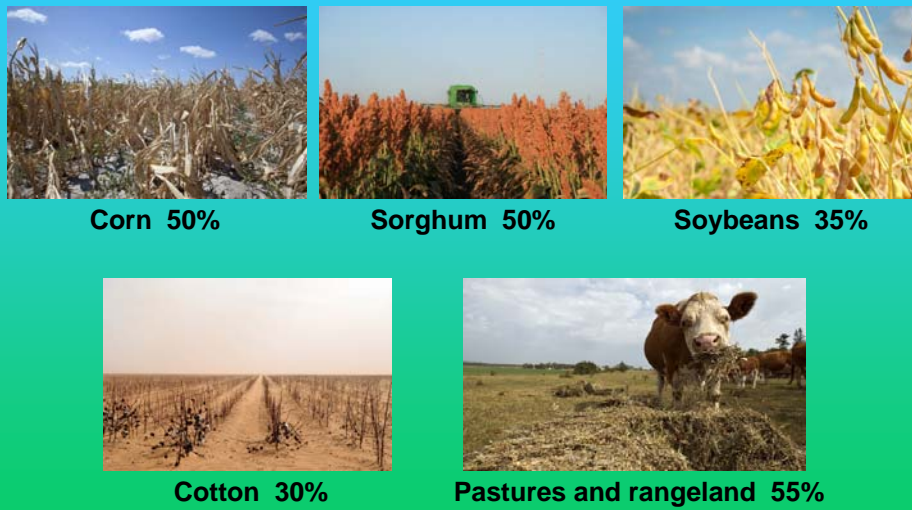


## Much of the U.S. has been experiencing severe drought

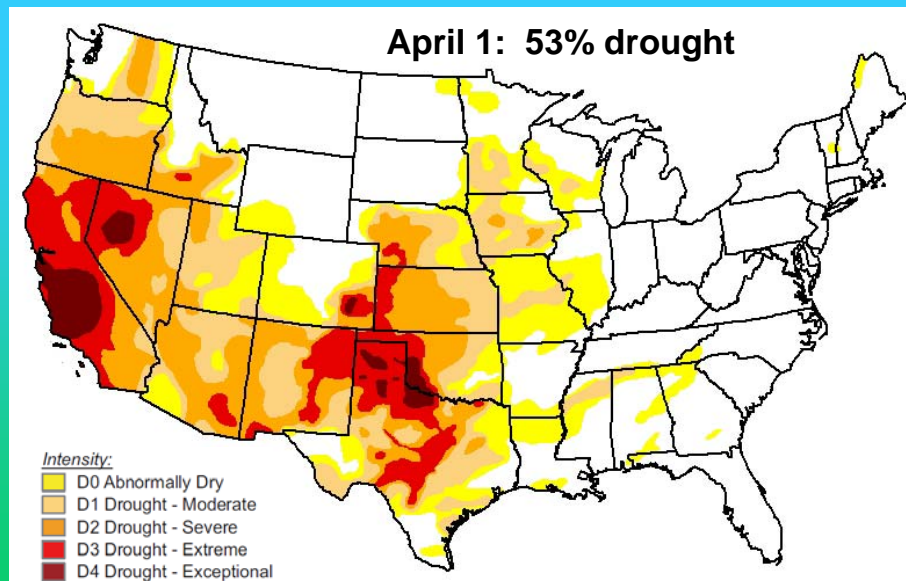


## Agricultural damage was tens of billions of dollars

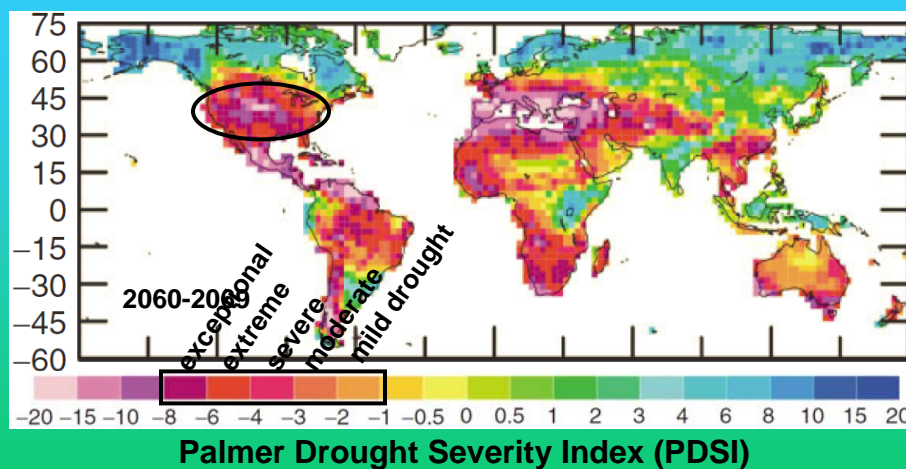
### U.S. crop losses in the summer of 2012:



## Is the U.S. still in drought?



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



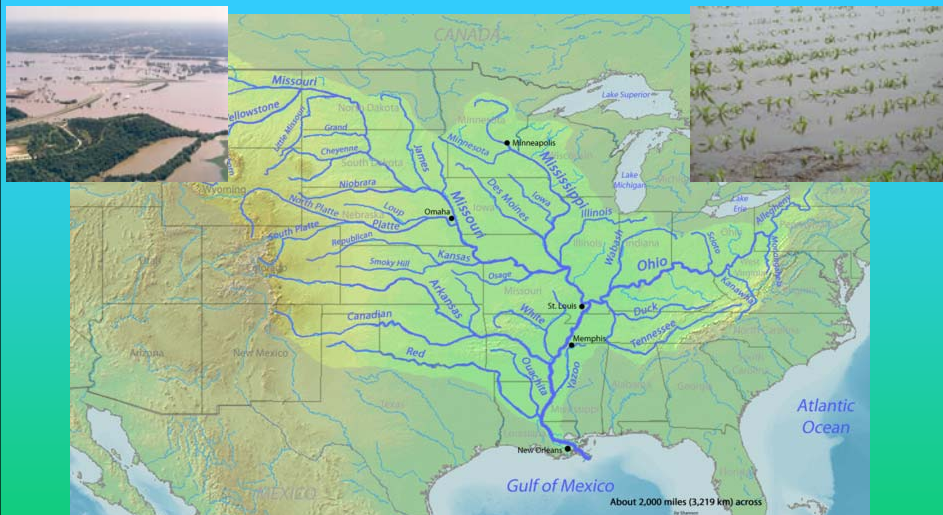
**- current drought indices will longer be sufficient**



## Severe rainstorms have already become more common



## Flooding is also likely to reduce future yields

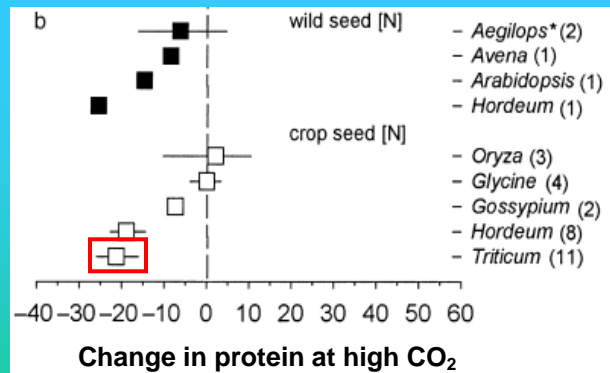


- in US Midwest, the probability of a flood event that destroys  $\geq 20\%$  of yield is predicted to double by 2030 and quadruple by 2090

## CO<sub>2</sub> fertilization includes a second effect

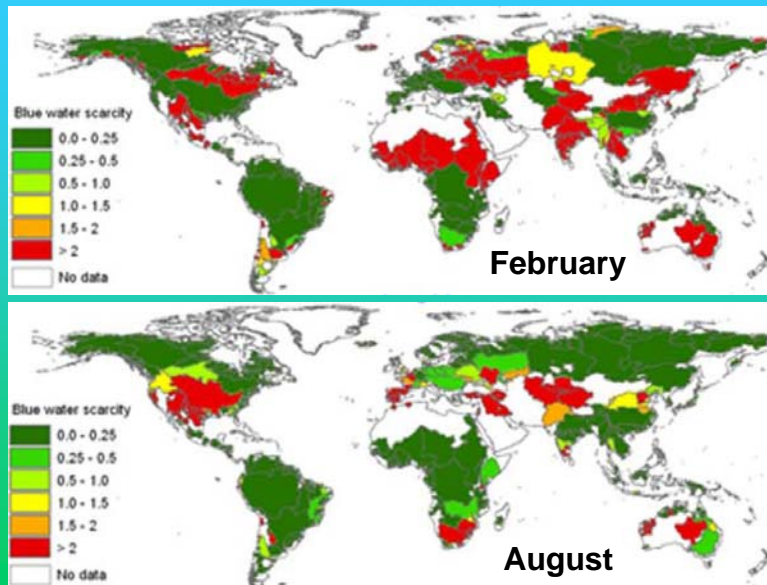


- wheat protein decreases by 20%



- 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

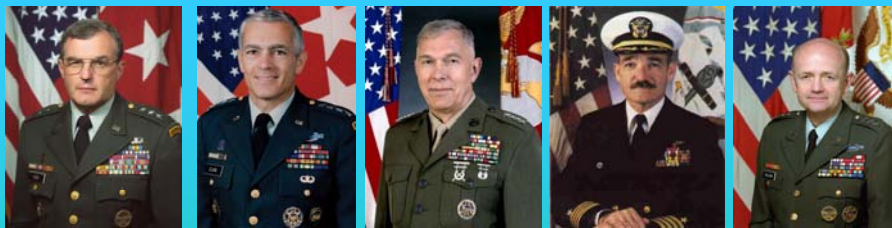


## Water scarcity is a U.S. national security threat



- 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:**

**CO<sub>2</sub> fertilization effect (larger size)**

**Longer growing season**

**Increased temperature**

**Altered precipitation**

**But do not include:**

**Increased droughts**

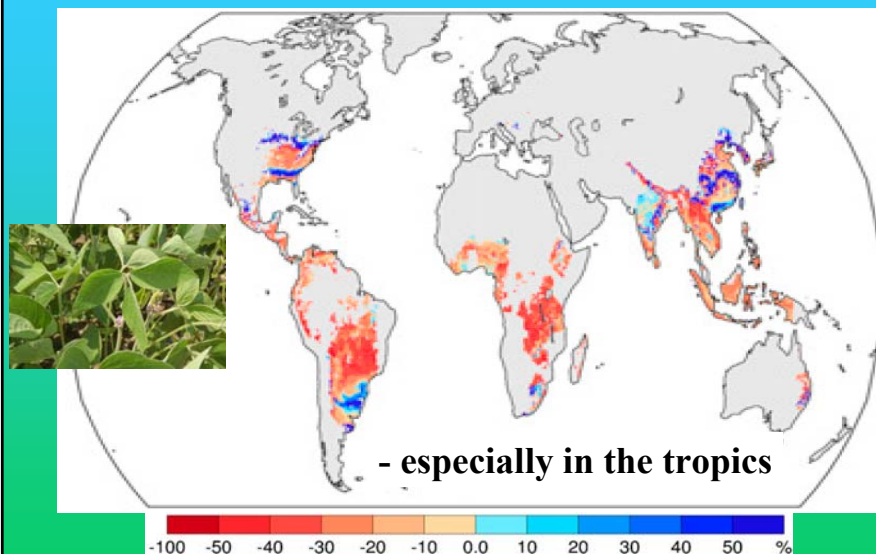
**Increased flooding**

**CO<sub>2</sub> fertilization effect (nutritional quality)**

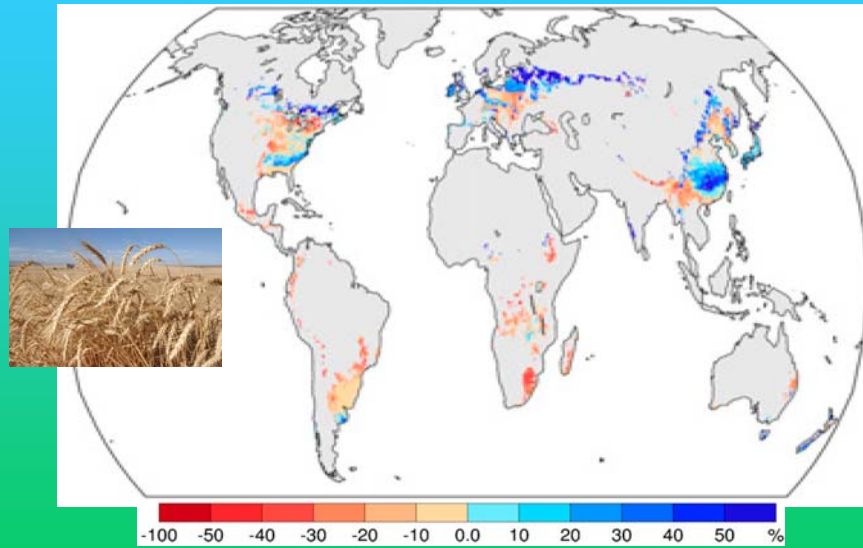
**Decreased water for irrigation**

**Increased pests**

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

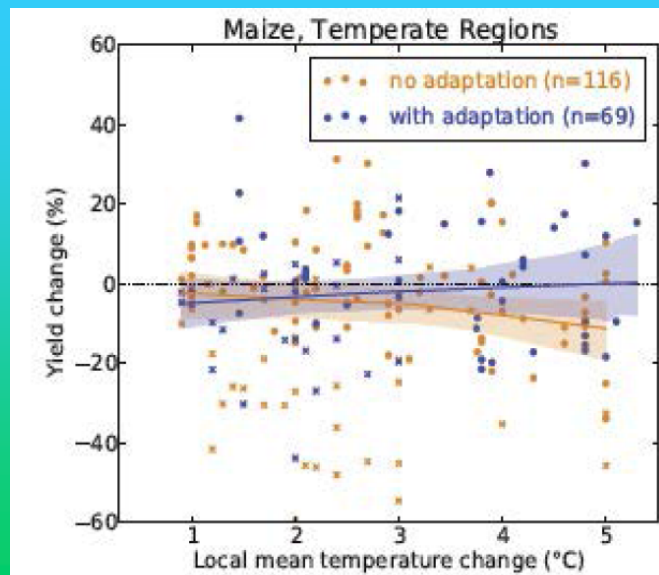


**By 2050, climate change is likely to have little overall effect on global yield of wheat**



**- more likely to decrease in the tropics**

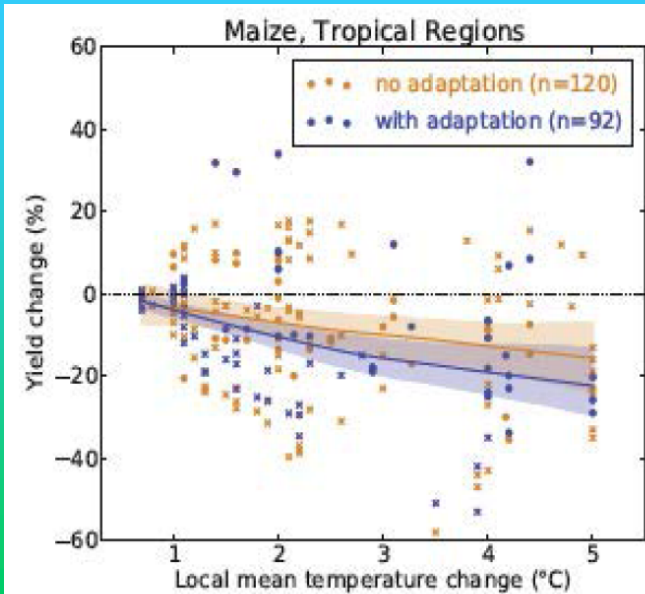
**Climate change may have little effect on yield of corn in temperate latitudes**



**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**

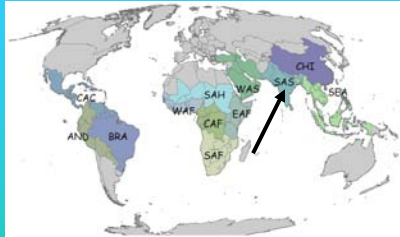
**- future U.S. corn and soybean yields may decrease  
dramatically**



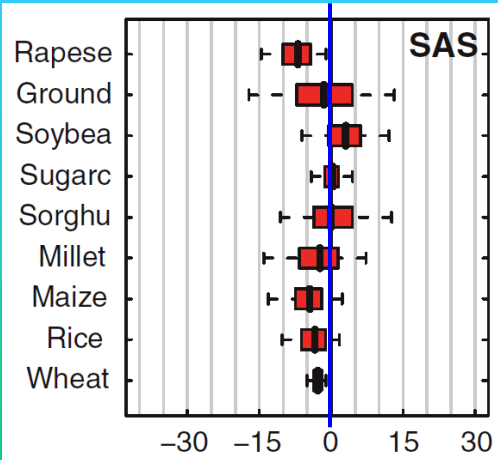
**20-25% decrease by 2050**

**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 CO<sub>2</sub> 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**

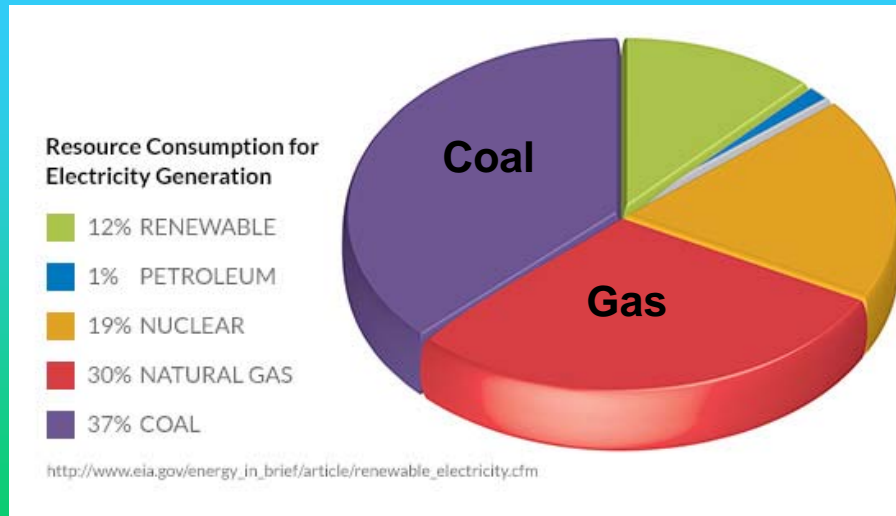


**Unfortunately, energy conservation is not a solution**



**- 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**

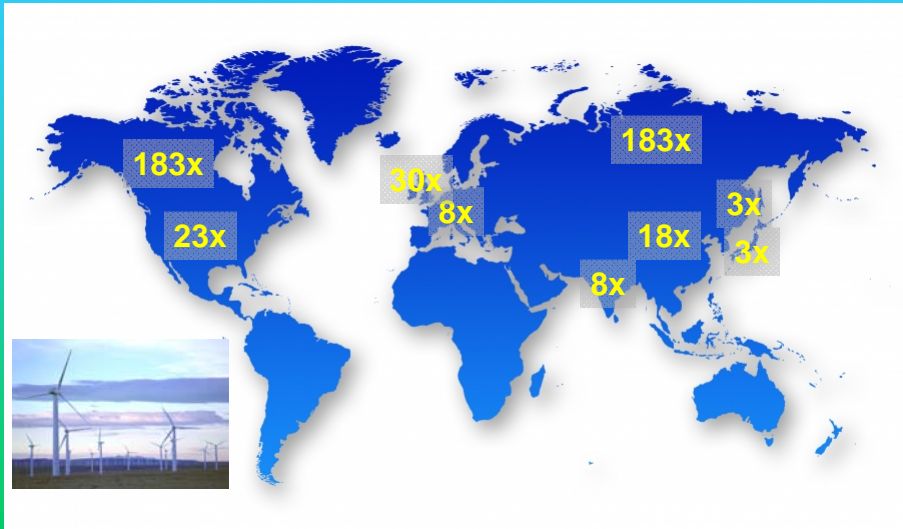


**Wind**

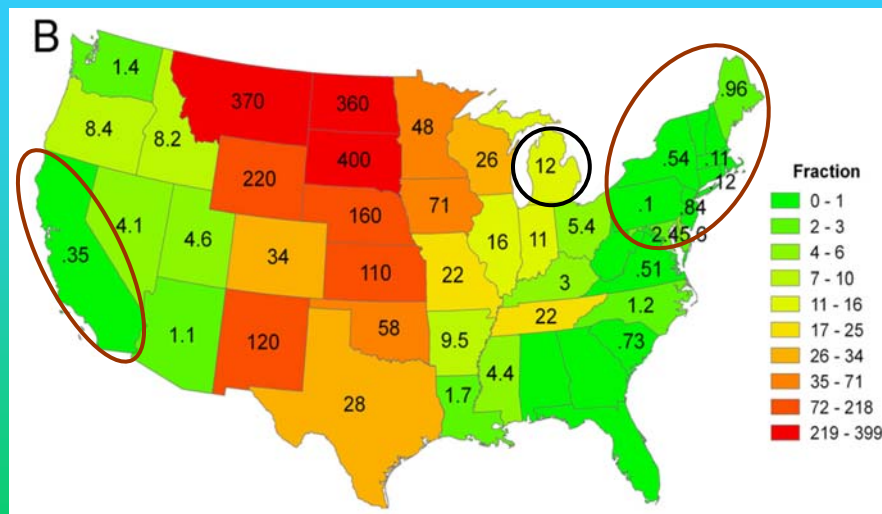
**Globally, we generate only 0.2% of our energy from wind, and only 0.1% from solar**

**Global wind potential is >40 times worldwide use**

**All 9 highest CO<sub>2</sub>-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



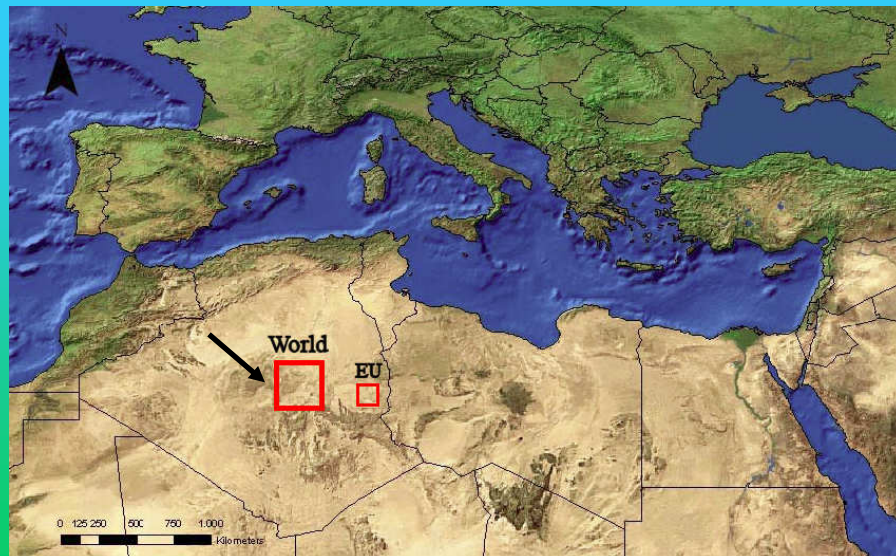
parabolic trough



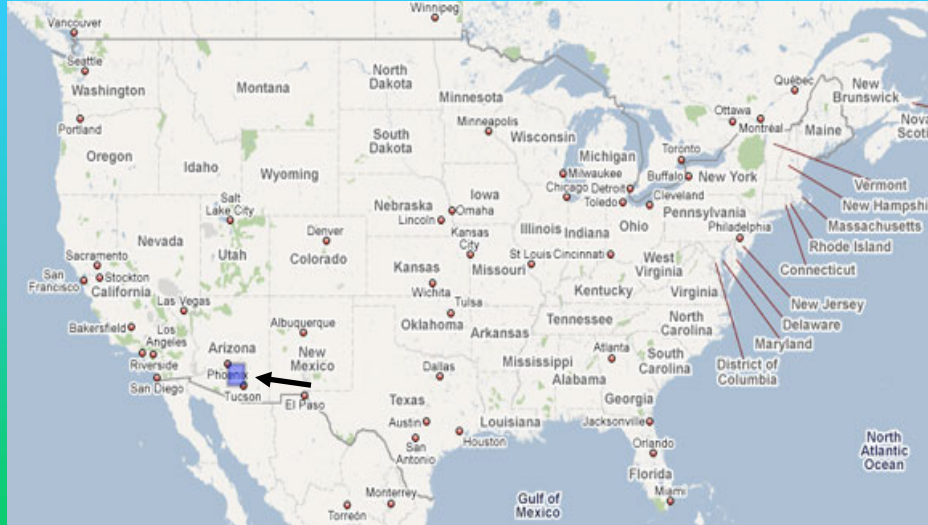
photovoltaics

**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**

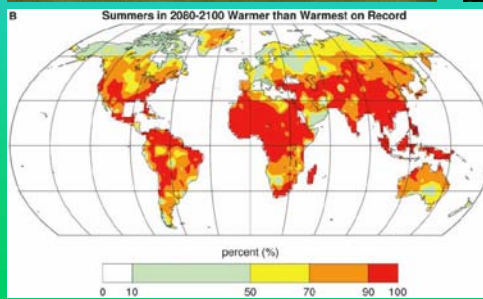


**parabolic trough**

**- 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**

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



## Educate others

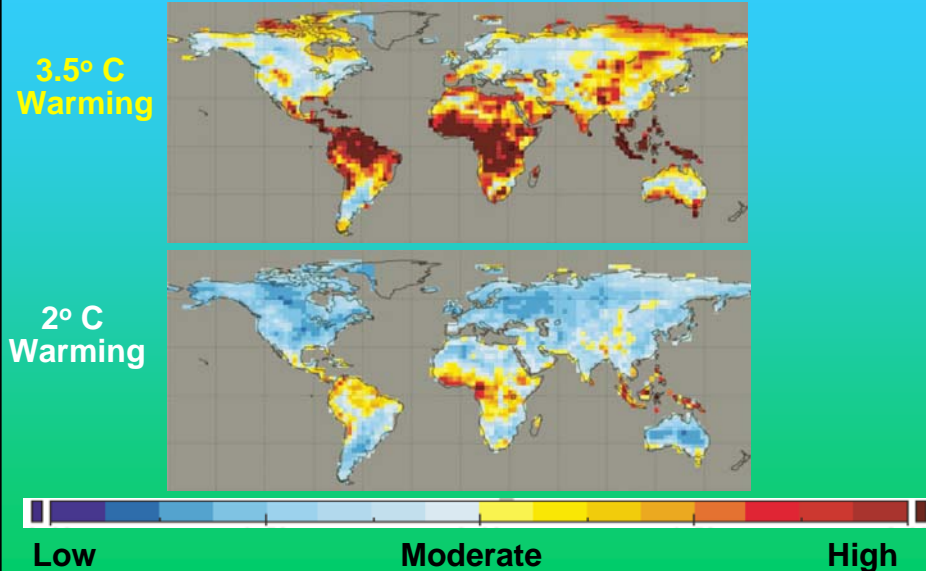


## Encourage policymakers to make smarter choices



**What would we gain by making these smarter choices?**

**Probability of species extinctions**



**Worst case scenario:**



**The future is in your hands**

