

# Ch. 14 Global Climate Change

**Earth has already warmed  $1.1^{\circ}\text{C}$   
( $1.98^{\circ}\text{F}$ ) since the 1850's**

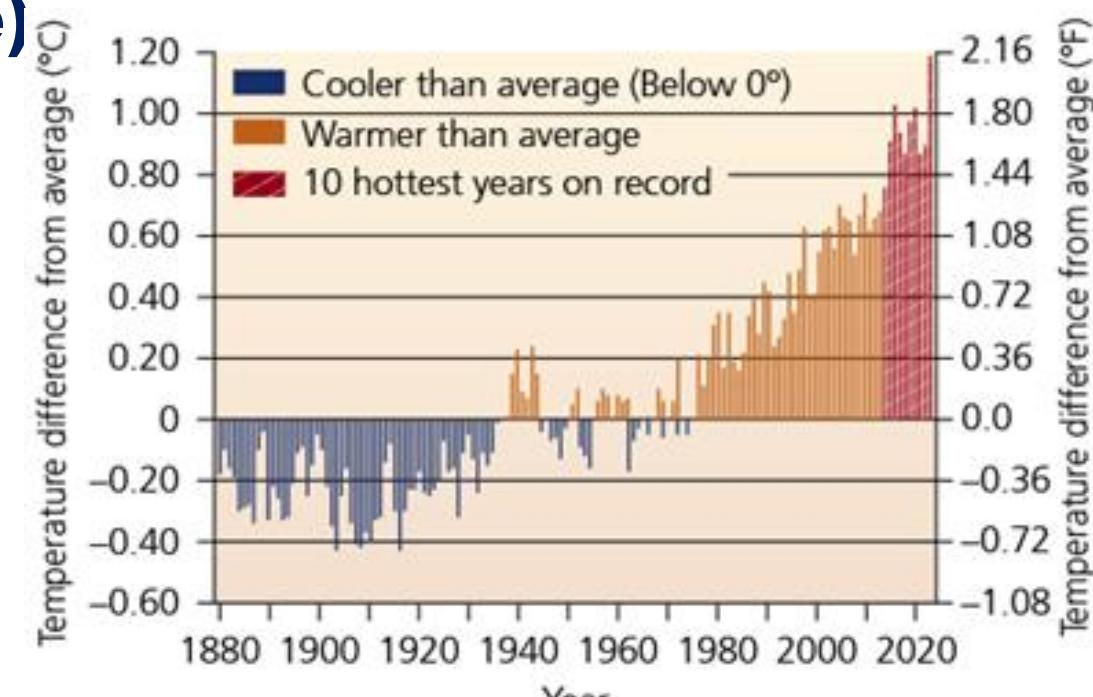
**We are on course to rise another  
 $2.7^{\circ}\text{C}$  ( $4.86^{\circ}\text{F}$ ) by 2050  
unless we address climate  
change now**

***~IPCC Report 8 Oct. 2018***



# What is climate change?

- **Climate:** an area's long-term atmospheric conditions (temperature, moisture, wind, precipitation, etc.)
- **Climate Change:** changes in temperature, precipitation, and the frequency & intensity of storms across the world
- **Global warming:** an increase in Earth's average temperature (underlying cause of climate change)
- Earth's climate varies naturally through time
- But, the current rapid climatic changes are primarily due to human activities
  - **Pollution from burning fossil fuels, deforestation, agriculture**



(a) Global temperature measured since 1880

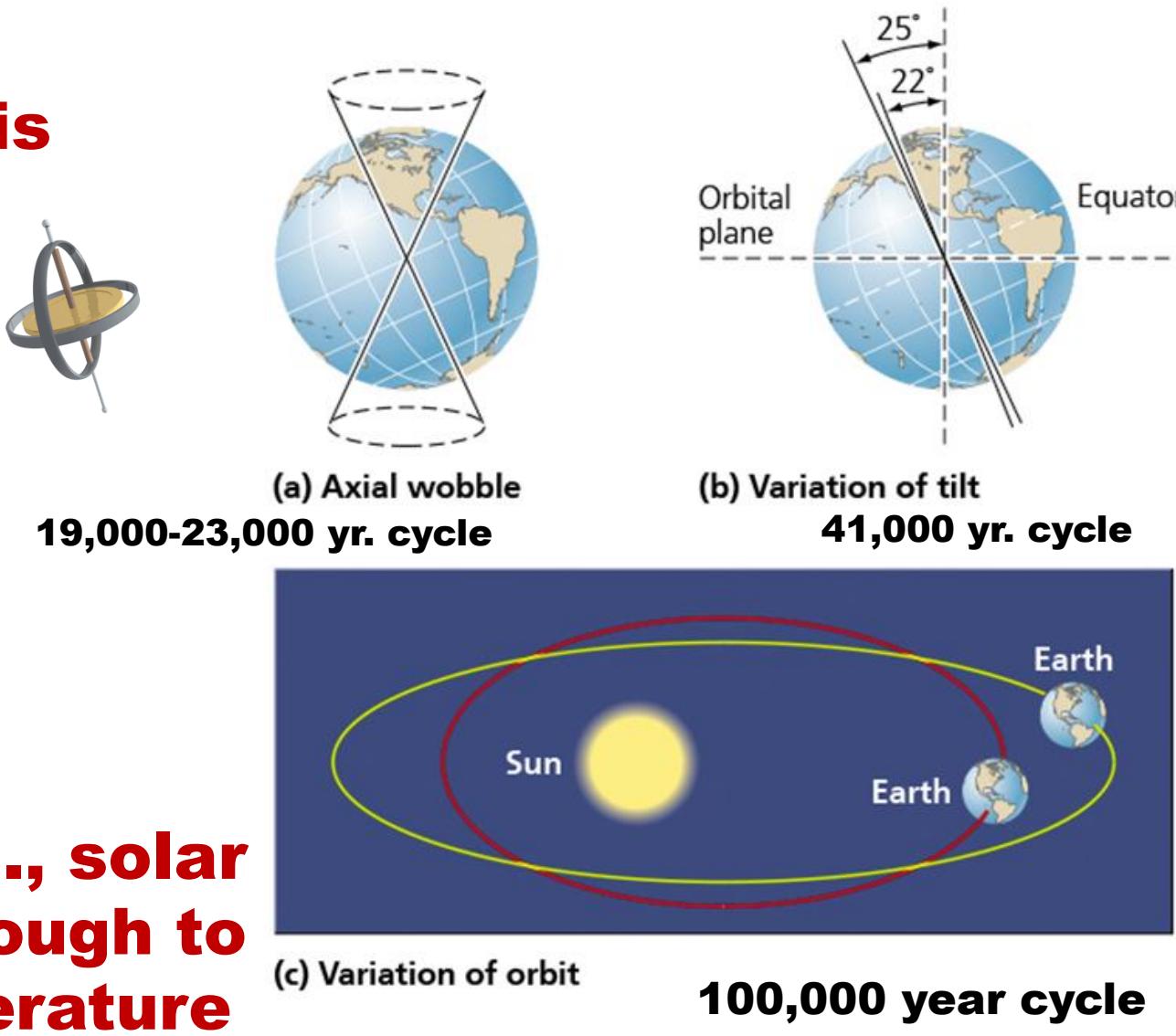
# **Natural factors influence climate**

- **Milankovitch cycles (3): periodic changes in Earth's rotation & orbit around the sun**
  - **Alter the way solar radiation is distributed over Earth & atmospheric heating**
  - **Triggers climate variation**
  - **EX: ice ages & warm interglacial times**
  - **Solar output: sun varies in radiation it emits**
    - **Variation in solar energy (e.g., solar flares) has not been great enough to change Earth's current temperature**

(a) Axial wobble  
19,000-23,000 yr. cycle

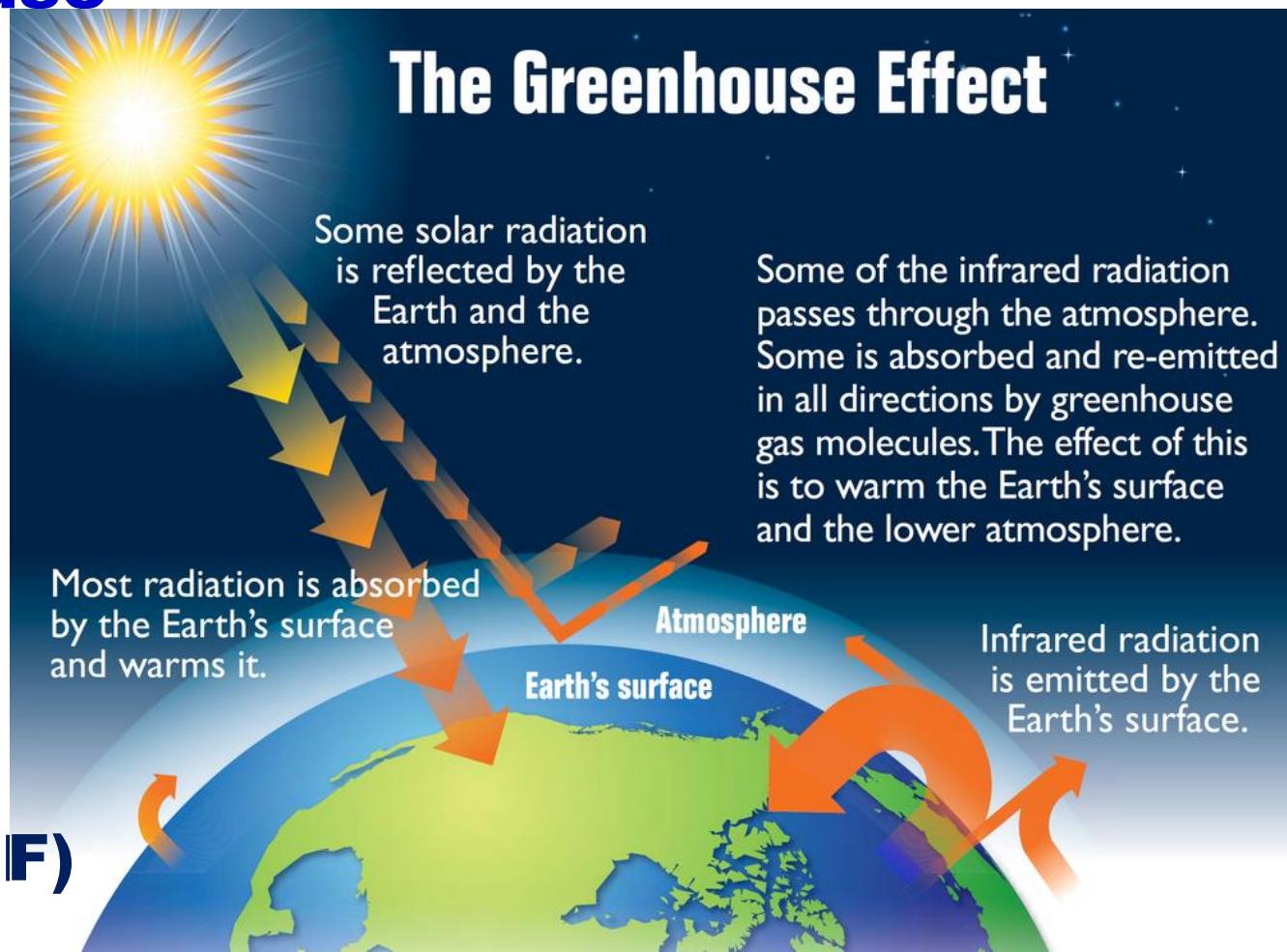
(b) Variation of tilt  
41,000 yr. cycle

(c) Variation of orbit  
100,000 year cycle

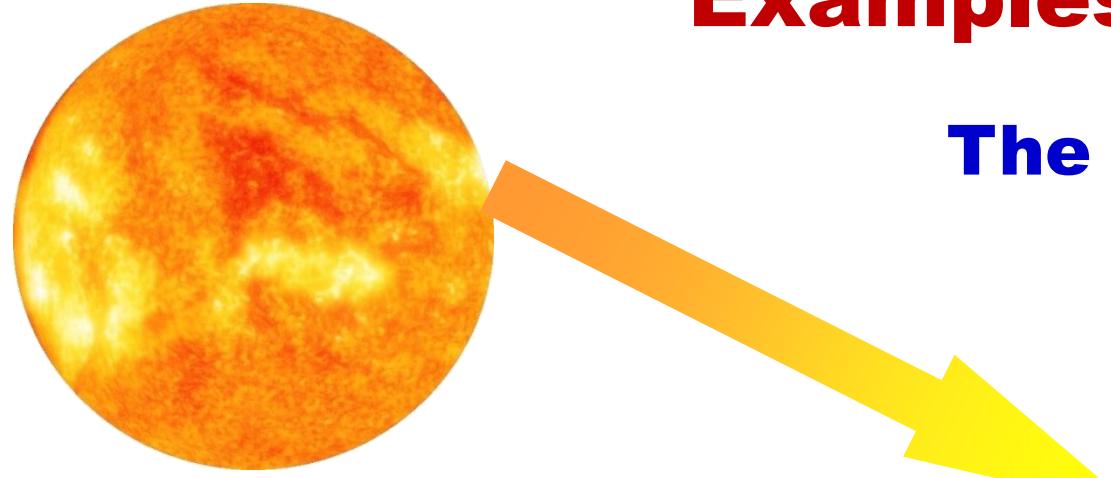


# Greenhouse Gases & the Greenhouse Effect

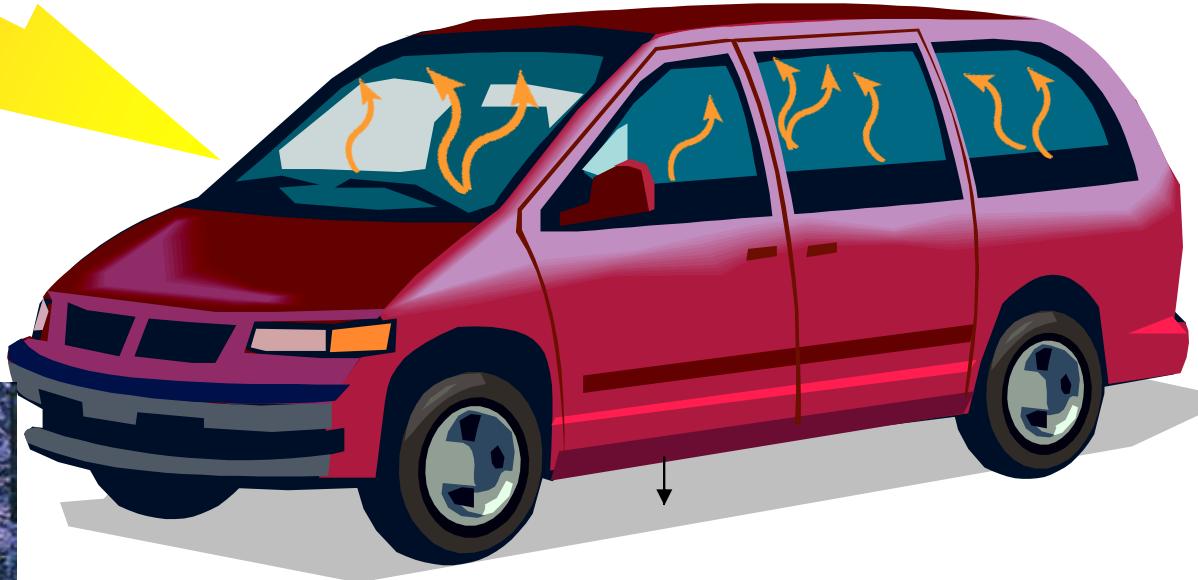
- When the Sun's energy reaches Earth's atmosphere, some of it is reflected back to space & the rest is absorbed & re-radiated by greenhouse gases
- Naturally occurring greenhouse gases include water vapor, carbon dioxide, methane, & nitrous oxide
- Greenhouse effect has been present throughout Earth's history
  - Has kept planet warm enough to support life
- Without it, Earth's average temperature would be -18°C (0°F)



# Examples of the Greenhouse Effect



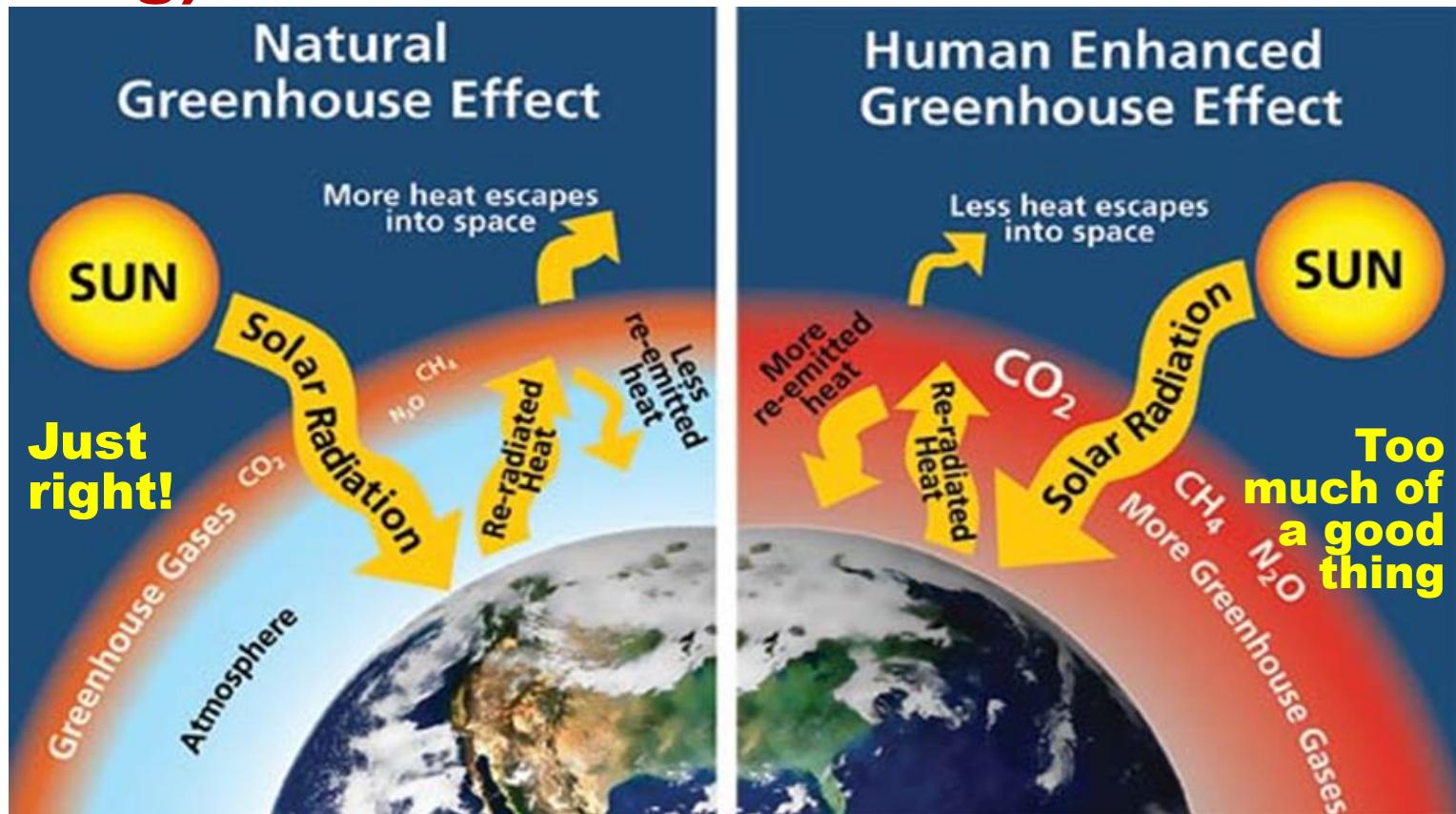
The Sun's energy passes through  
the car's windshield



In Earth's atmosphere, greenhouse  
gases act like panes of glass in a  
greenhouse, trapping heat

# Enhanced Greenhouse Effect

- The problem we now face is that human activities are greatly increasing the concentrations of greenhouse gases
  - Burning fossil fuels (coal, oil, & natural gas), agriculture, & deforestation (land clearing)
- This enhanced greenhouse effect is causing the accelerated warming of the Earth known as global warming
- GHGs warm Earth by absorbing energy & slowing the rate that energy escapes to space, acting like a blanket insulating Earth

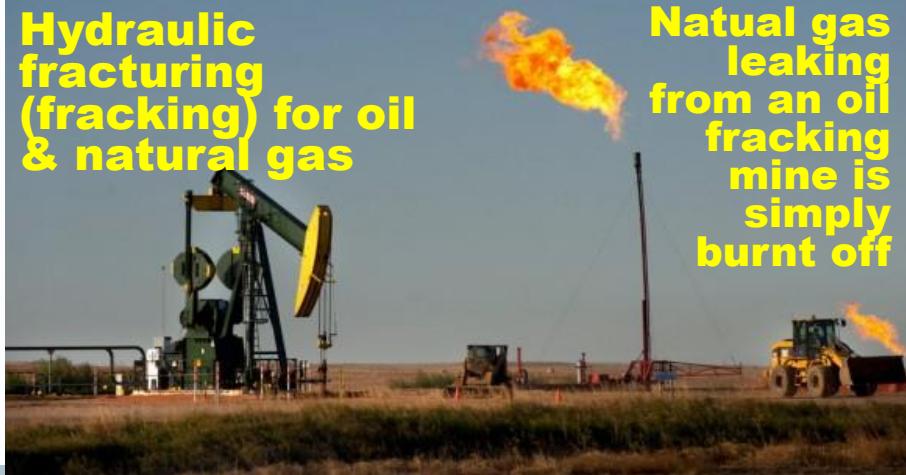




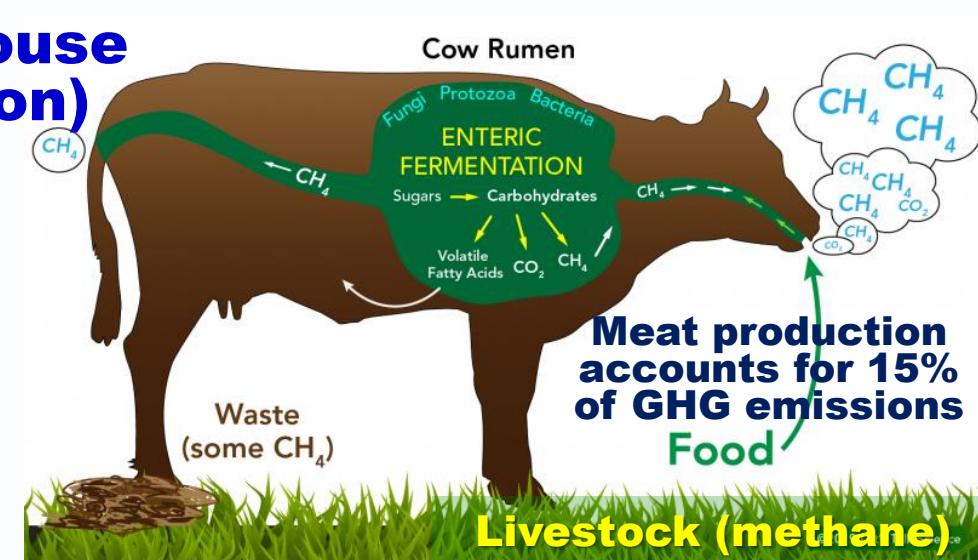
Fossil Fuel Mining

## Causes of Enhanced Greenhouse Effect (A Form of Air Pollution)

Hydraulic fracturing (fracking) for oil & natural gas



Natural gas leaking from an oil fracking mine is simply burnt off



Burning Fossil Fuels  
(Transportation, Industry, Power stations)

Garbage & landfills



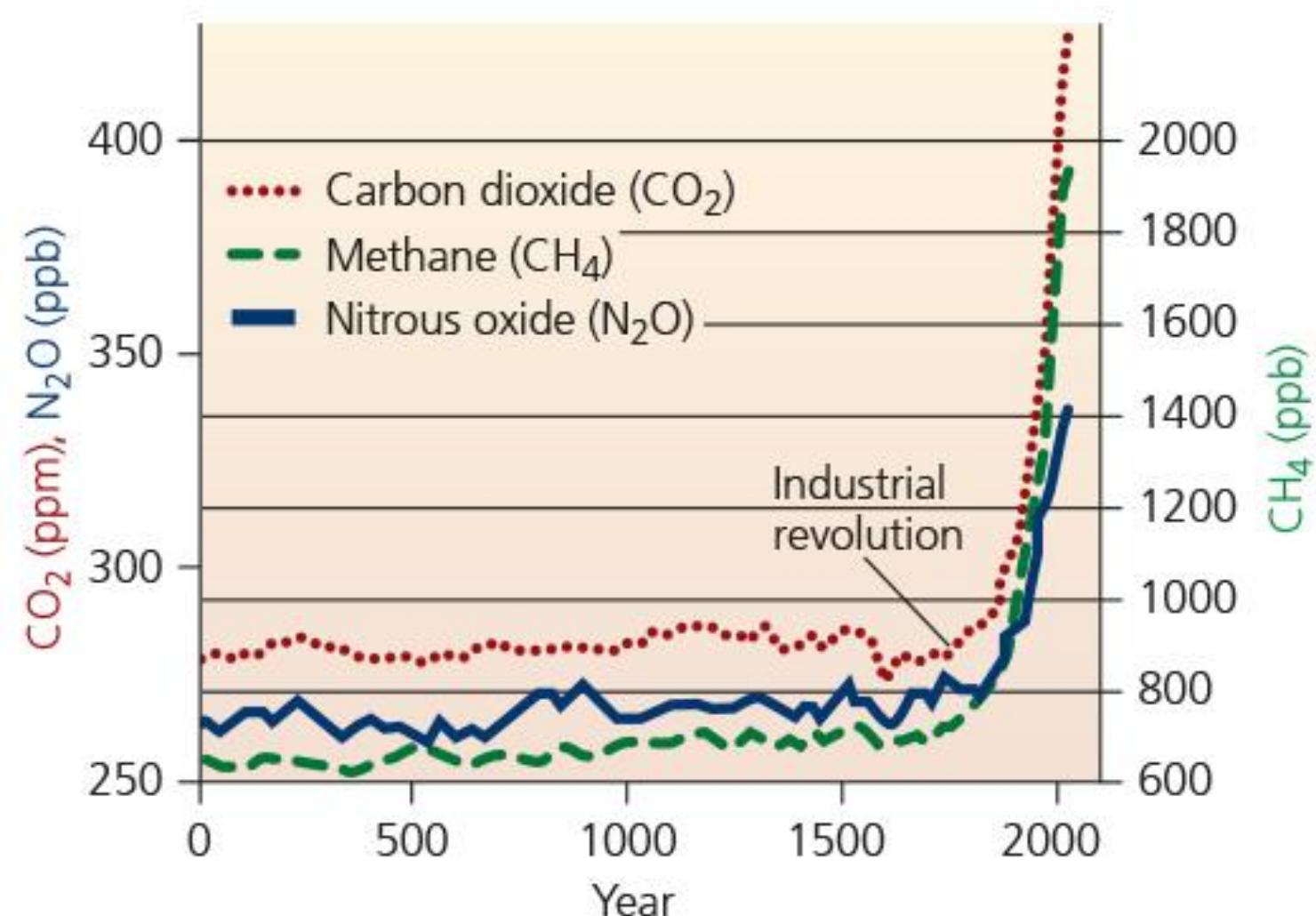
Deforestation

### Human Sources of GHGs

- **CO<sub>2</sub>:** fossil fuels, agriculture, deforestation,
- **Methane:** agriculture, fertilizer, landfills
- **Nitrous oxide:** fossil fuels, agriculture, fertilizer
- **Flourinated gas:** Man-made chemicals (refrigerants-CFCs, HFCs)

# **Greenhouse Gas Concentrations Are Rising Fast**

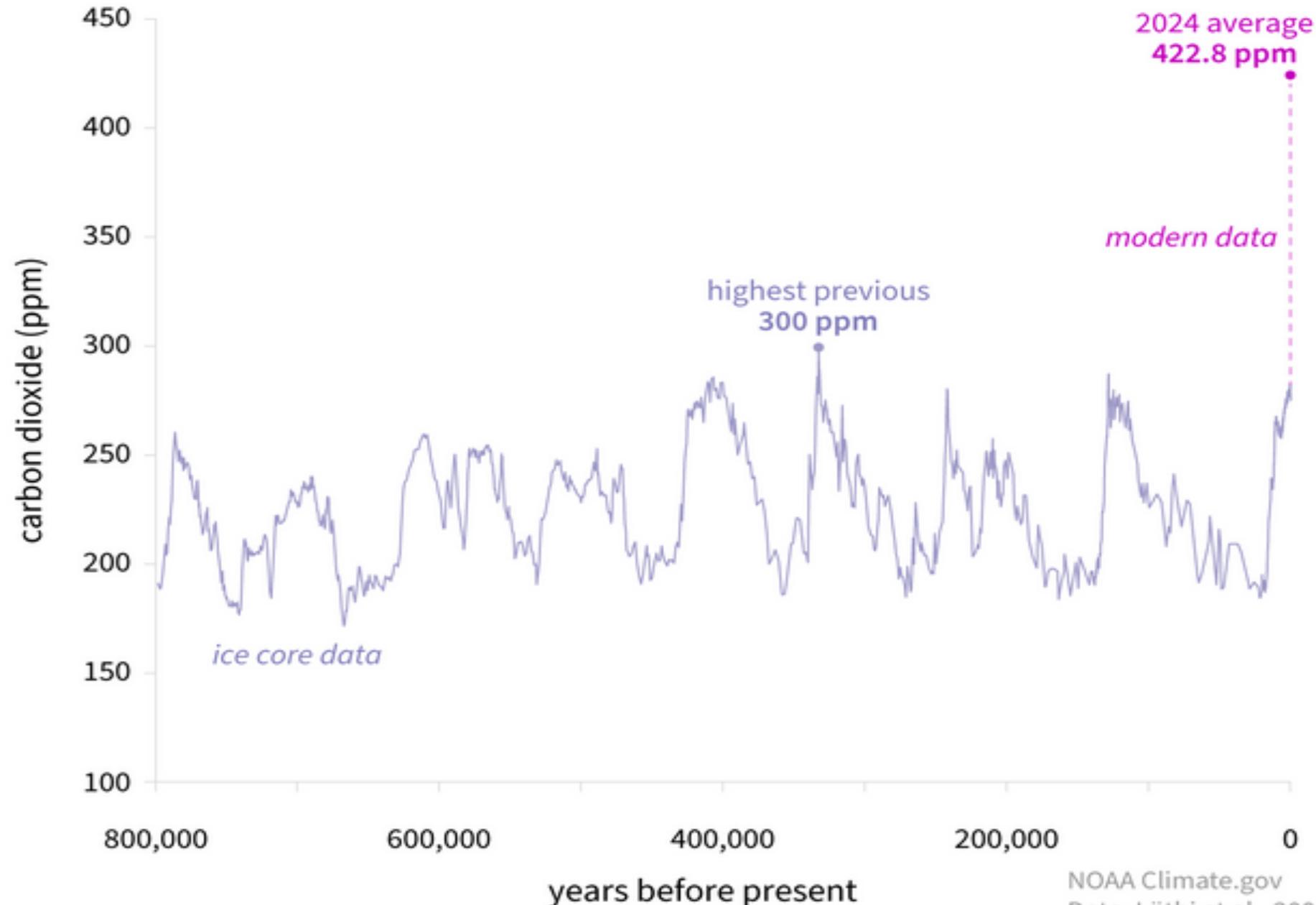
- A Human-generated intensification of the greenhouse effect has taken place over the past 250 years
  - **CO<sub>2</sub> is main driver of climate change because we emit so much of it & it lasts for ~1,000 years**
  - **But, methane, nitrous oxide,& fluorinated gases absorb much more heat than CO<sub>2</sub>**
- Since the start of the industrial revolution ~1750, global concentrations of CO<sub>2</sub>, CH<sub>4</sub>, & N<sub>2</sub>O in the atmosphere have increased markedly**



# CARBON DIOXIDE OVER 800,000 YEARS

**Carbon Dioxide  
is Rising**

**Carbon dioxide  
levels today are  
higher than at  
any point in at  
least the past  
800,000 years**



# Extra Heat is Driving Global Warming Impacts

**Dirty Air**

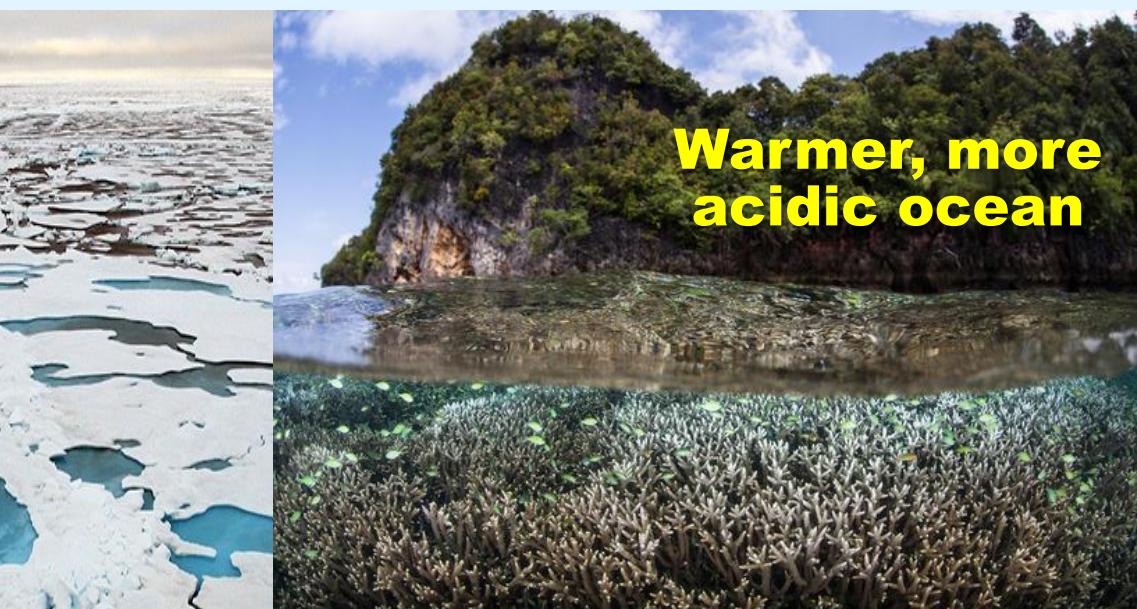
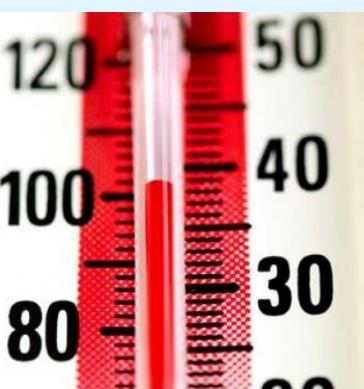


**Imperiled ecosystems & changing habitat ranges for plants & animals**



**Reduced snow & sea ice**

**Heat Waves**



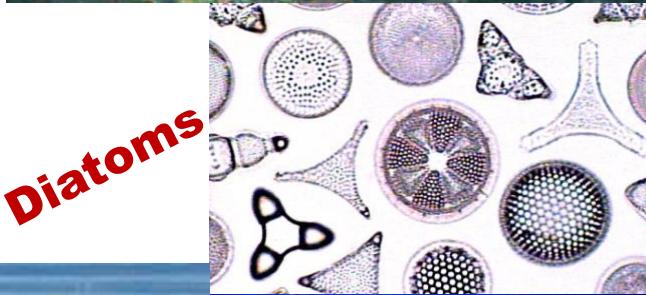
**Warmer, more acidic ocean**



**Heavy rainfall & flooding**

# Global Warming Impacts

- Sea level rising (melting ice caps, ice sheets, & glaciers, etc., expansion of warmer water)
  - Loss of low-lying coastal land
- Alter strength of ocean currents
- Extreme droughts, heat waves, heavier rainfall
- ↑ intensity of Tropical storms/Hurricanes
- Ocean acidification
- Warmer ocean:
  - Fewer plankton (diatoms, krill)
  - Extinction of species with limited temperature ranges (coral, polar bears)



A photograph showing three polar bears on a field of sea ice. A large adult bear stands in the center, looking towards the right. To its left, a smaller cub walks away from the camera. To its right, another cub stands and looks towards the camera. The background consists of a vast expanse of broken sea ice floating on dark blue water.

**Polar Bears – the 1<sup>st</sup> species listed on the  
Endangered Species Act as threatened with  
extinction because of climate change**

*~May 2008 – U.S. Fish & Wildlife Service*

**2/3 of world polar  
bear population could be  
extinct by 2050**

**Polar bears  
walk across the  
sea ice to  
access their  
seal prey**

## Sea Level Rise

- Global sea level has risen ~9.3 inches in last 120 years
- It is projected to rise another 1 to 4 feet by 2100
- Due to added water from melting land ice & expansion of seawater as it warms
- Storm surges & high tides could combine with sea level rise & land subsidence to further increase flooding in many regions

**Due to rising seas,  
extreme flooding that used  
to occur once every 100  
years is expected to recur  
every 6 years by 2050  
~IPCC**



# Two Causes of Sea Level Rise

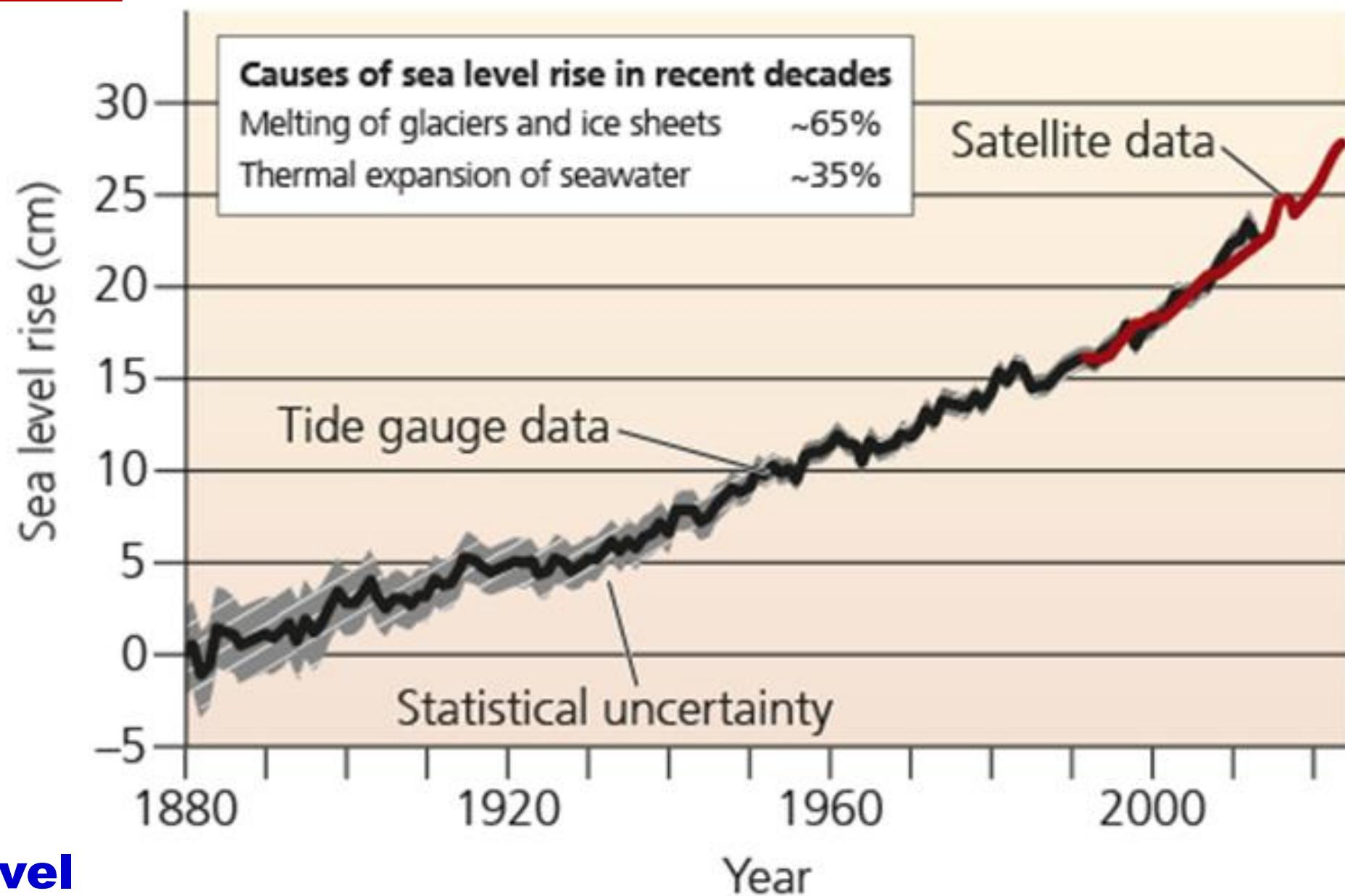
## **1. Thermal expansion:**

**As water warms,  
it takes up more  
space**

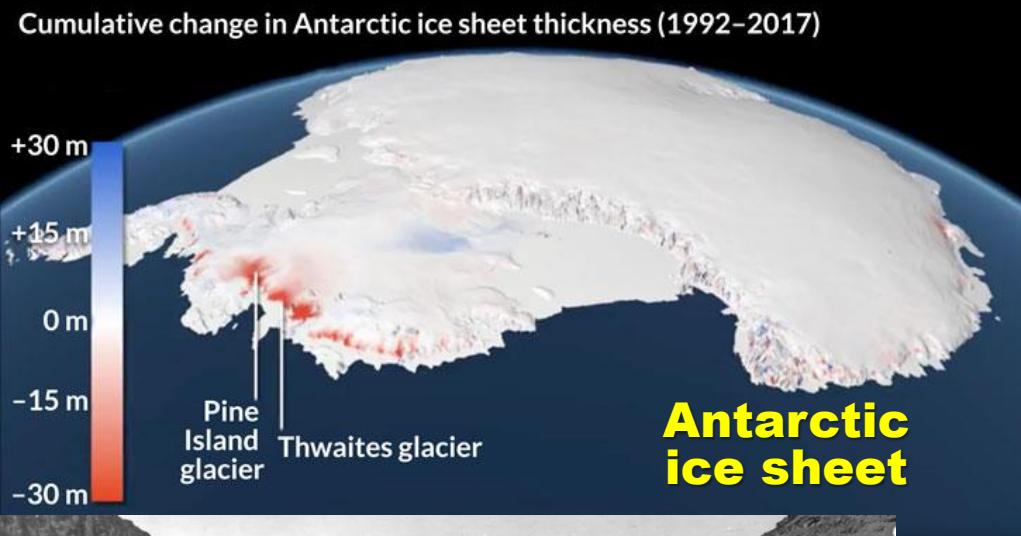
**At current rates,  
expansion alone  
could cause sea  
level to rise 0.5m  
(20 in.) by 2100**

## **2. Melting of ice on the land:**

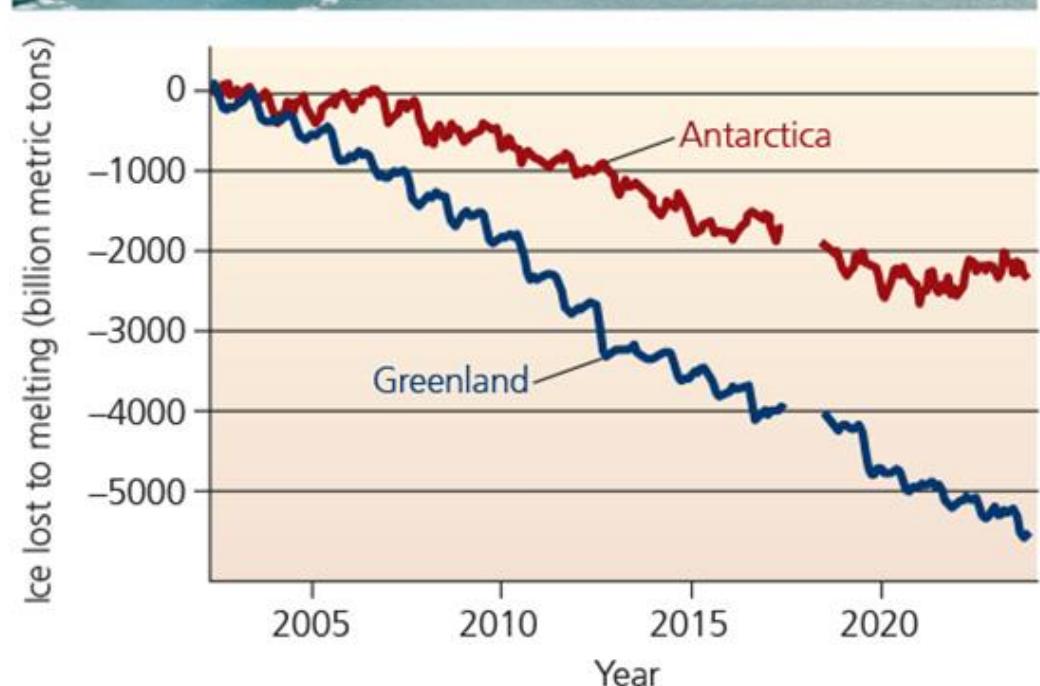
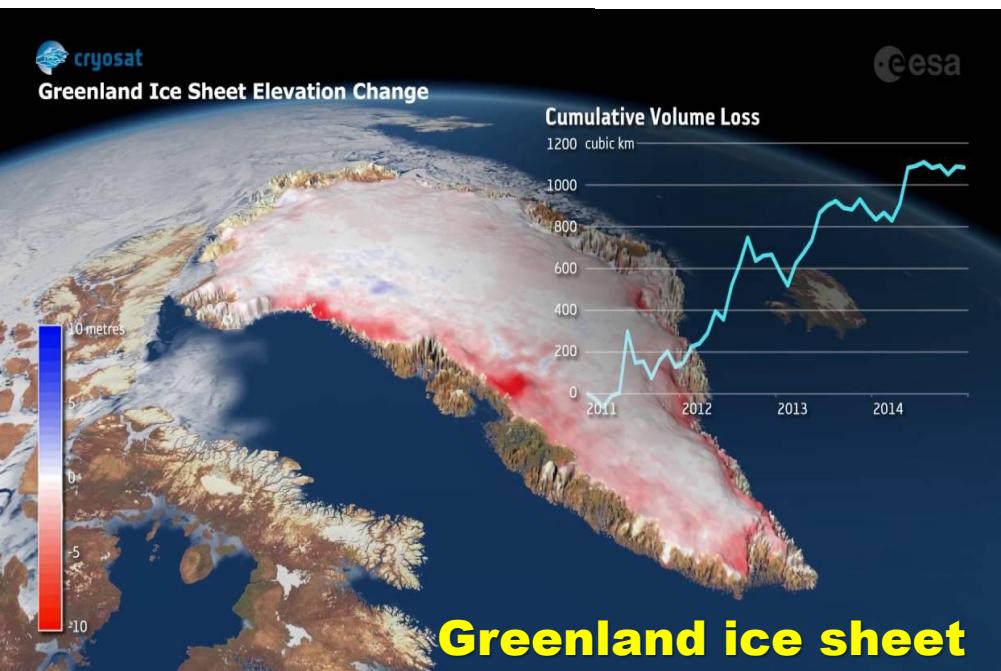
**Melting glaciers,  
ice caps, & ice  
sheets dump  
freshwater  
into the sea,  
increasing sea level**



# Where is Melting Ice Coming From?



**Much of Earth's fresh water is frozen in mountain glaciers & in ice sheets on Greenland & Antarctica**



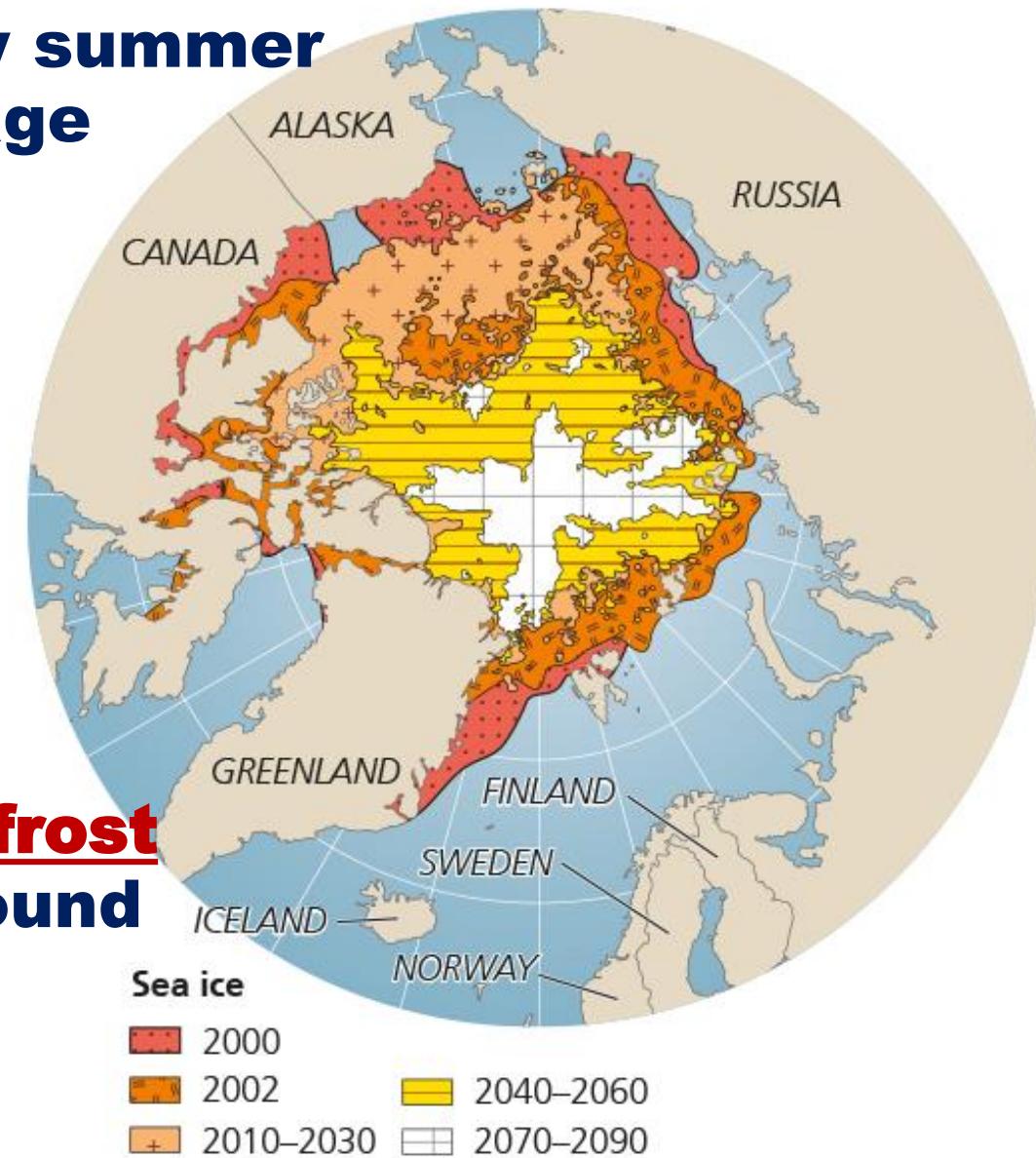
(a) Ice lost to melting in Greenland and Antarctica

- When this ice melts or calves off, the water flows into the oceans and sea levels rise

# Melting Ice Has Far-Reaching Effects

- Loss of Arctic sea ice has opened new summer shipping lanes in the Northwest Passage
- As snow & ice melt, less white, reflective surfaces (ground or surface water) are exposed
  - Reduces Earth's capacity to reflect light, causes more warming as darker surfaces absorb heat
- Arctic warming is also thawing permafrost in Tundra, causing release of underground methane, further intensifying warming

**Little Arctic summer sea ice is expected by 2070**

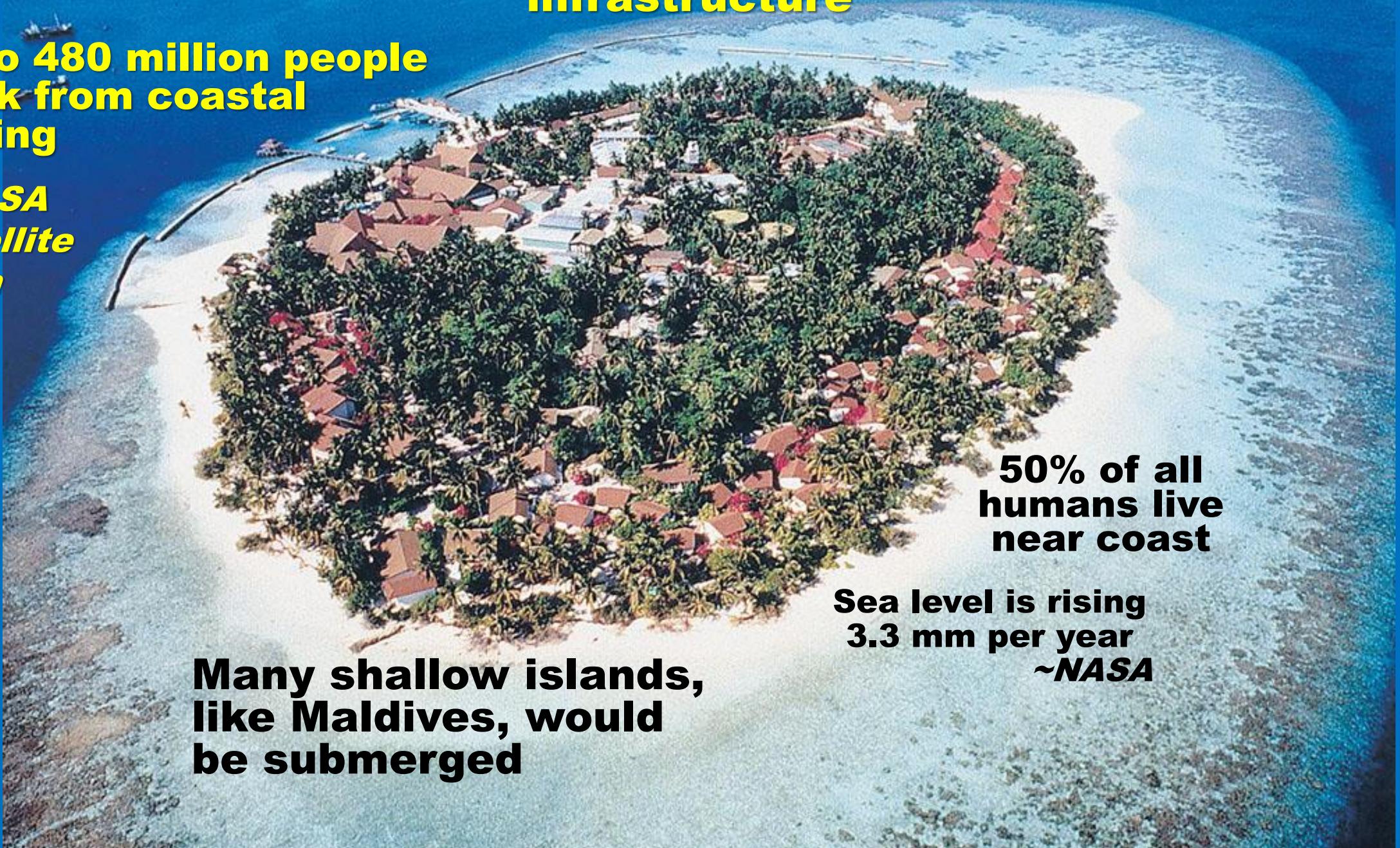


Observed and predicted melting of Arctic sea ice

# **Coastal sea level rise threatens people, ecosystems, & infrastructure**

**340 to 480 million people  
at risk from coastal  
flooding**

*~NASA  
satellite  
data*



**50% of all  
humans live  
near coast**

**Sea level is rising  
3.3 mm per year**

*~NASA*

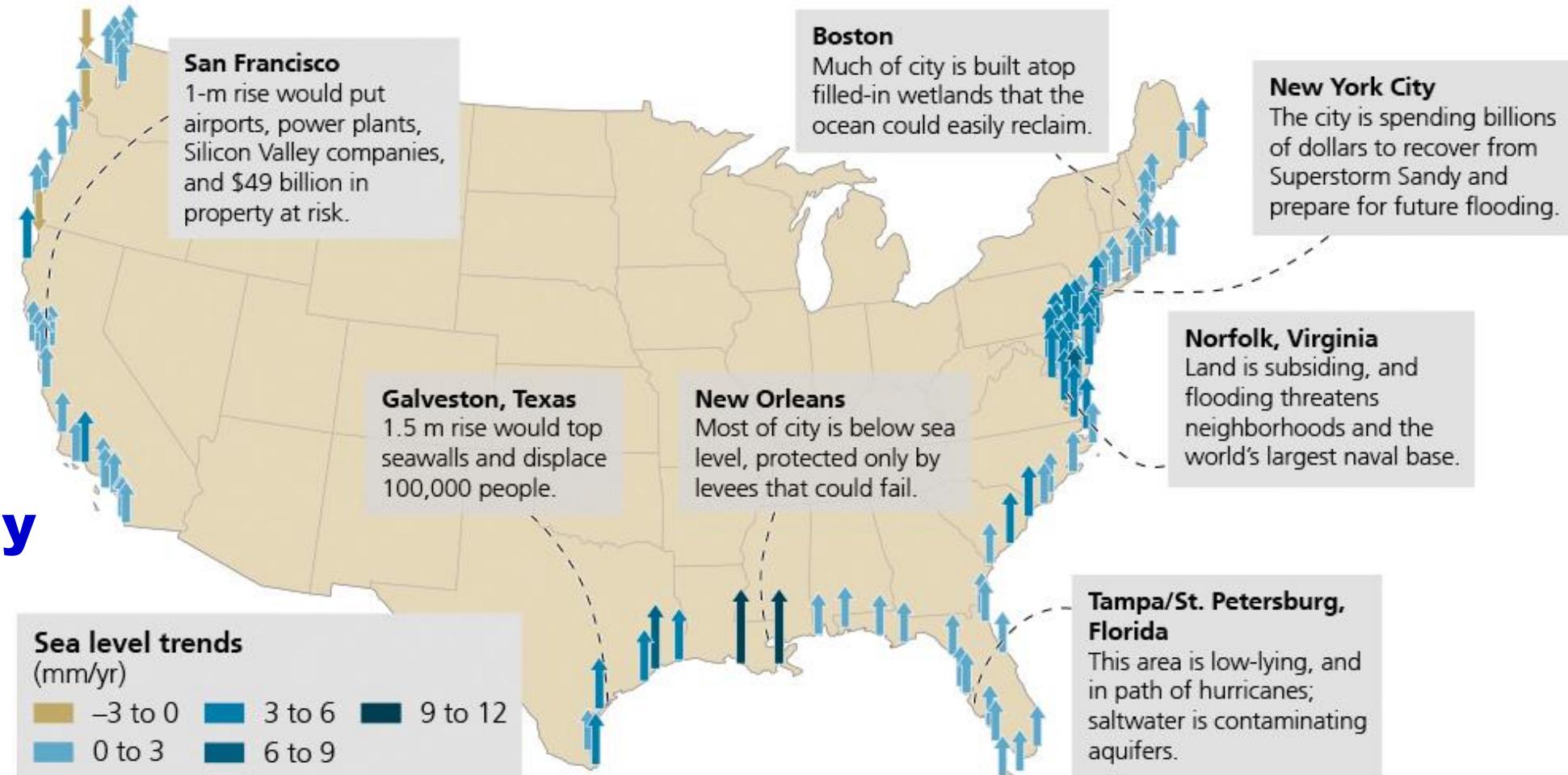
**Many shallow islands,  
like Maldives, would  
be submerged**

# Rising Sea Levels Will Affect Hundreds of Millions of People

Rising sea levels are putting many U.S. cities at risk of costly damage

- Could devastate coastal cities with flooding, erosion, loss of land area, stronger storms.....

• Globally, economic costs to cities from rising seas & flooding could amount to \$1 trillion every year by 2050





Amsterdam,  
Netherlands



Alexandria,  
Egypt



Shanghai, China



Miami, Florida

# Sea Level Rise in California



San Francisco  
International  
Airport

- El Niño weather events further raise coastal sea levels & increase rainfall for several months
- 25 million coastal residents (largest number in USA)
- 2/3 of Southern CA beaches on track to disappear

Average sea level rise along all of CA's coast is expected to be 30 cm (12") by 2050 & 91 cm (36") by 2100



Balboa Peninsula,  
Newport Beach

# Coral Bleaching:

- Occurs when coral animals expel their symbiotic algae (zooxanthellae) in response to water temperatures that exceed 1°C (1.8°F) for more than a few weeks

➤ Can kill coral

## Ocean Acidification

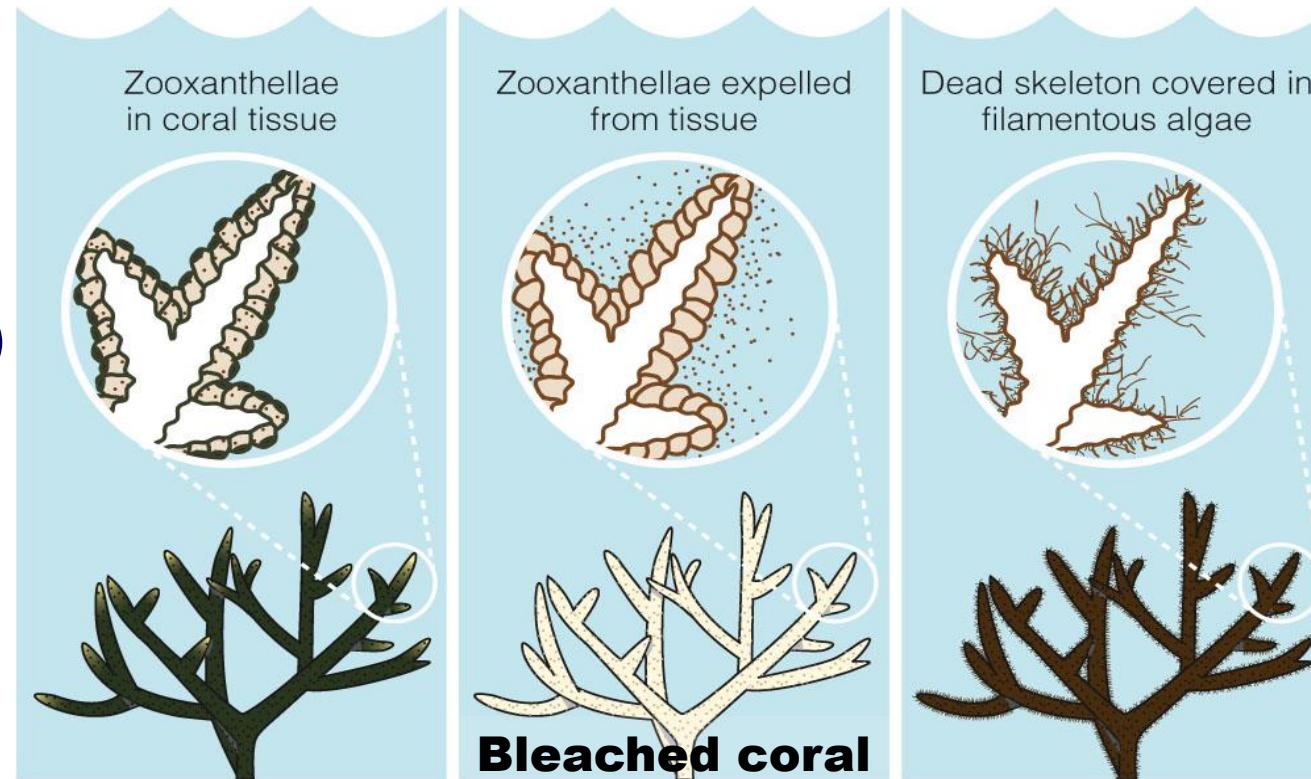
- Ocean acidity ↑ as the ocean absorbs more carbon dioxide (CO<sub>2</sub>) from burning fossil fuels

– Oceans absorb CO<sub>2</sub> from air

- Organisms cannot form strong shells or exoskeletons in acidic conditions

- Ocean acidity increased 30% in last 200 years as ocean....

has taken up ~35% of excess CO<sub>2</sub> from burning fossil fuels



Healthy coral

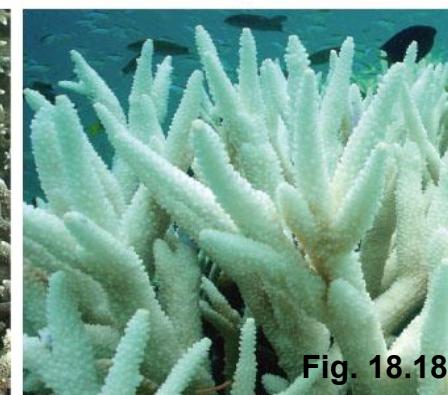


Fig. 18.18, p. 505



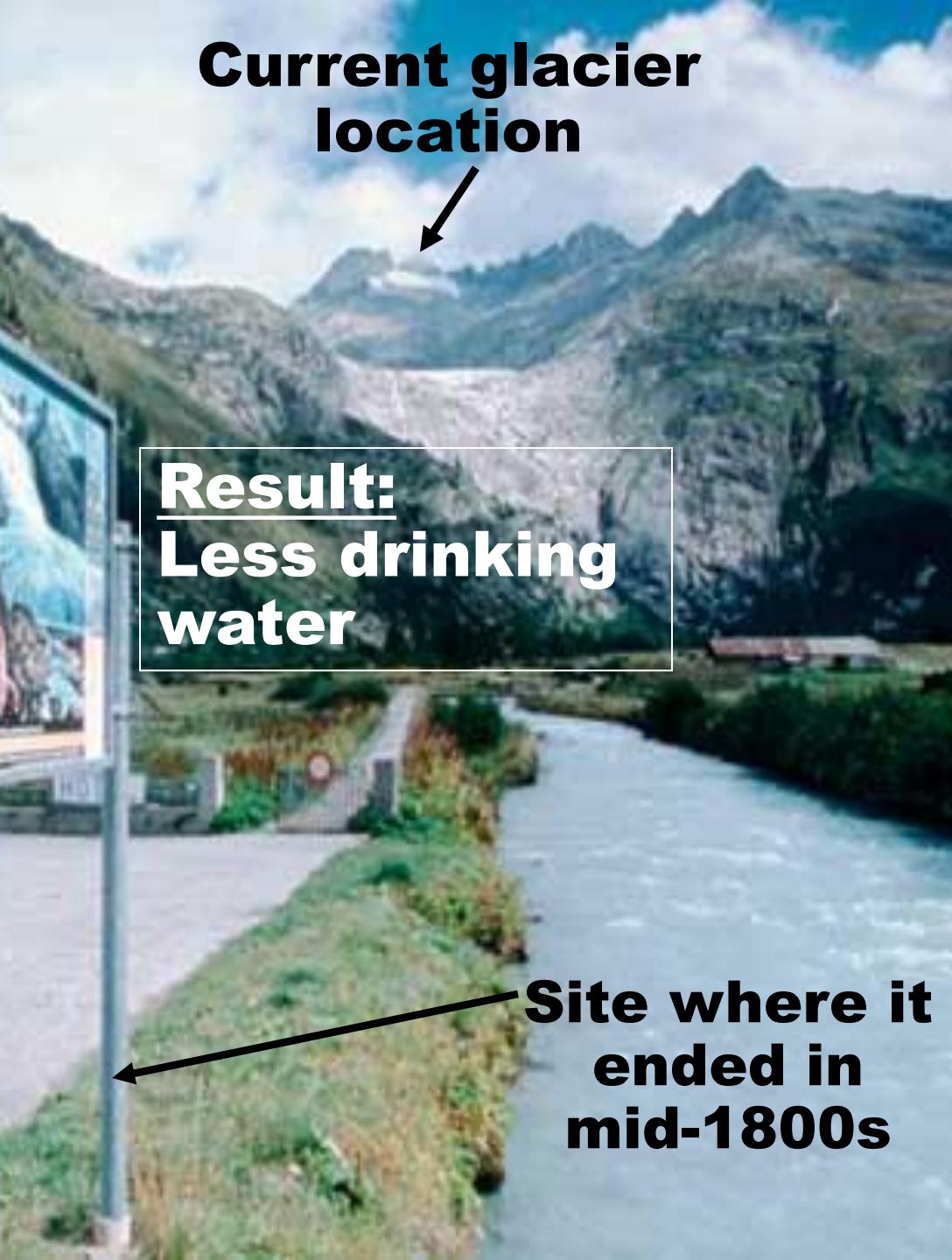
# **Retreating Glaciers**

**Rhone Glacier  
Valais, Switzerland**



**Current glacier  
location**

**Result:  
Less drinking  
water**



**Site where it  
ended in  
mid-1800s**



## Ethiopia

**Drought (hotter & drier)  
near equator & arid biomes  
causes crop failure**

**Result: Higher Prices &  
Food Shortages**

## Farms Damaged By Climate Change

**Strong storms & extreme rainfall flood farms in rainy areas**



**Flooded bean farm in England**

**Sea level rise floods rice field**



**Bangladesh**

**A warmer atmosphere holds more moisture, which causes heavier rainfall & stronger storm systems, followed by more frequent flooding**



In the past, a storm like this may occur in a particular area once in a lifetime. On a warmer planet, a storm like this may occur once every decade.

Hurricane Florence  
in North Carolina  
September 2018

Extreme rain follows extreme drought (evaporation puts more water in atmosphere, dry soils cannot absorb rainfall)

**Reducing air pollution from burning fossil fuels will greatly reduce heart disease, cancer, strokes, asthma, dementia, & prolong lives**

**Polluted air contains high levels of dangerous gases & particulate matter, small enough to enter the human bloodstream through the lungs—a problem that contributes to an estimated 7 million premature deaths each year**

**Climate Change is caused by the same air pollution that harms our health**

**Many world leaders now recognize that solving climate change (air pollution) is no longer a choice, but a necessity to protect human health**

**Worsening Health**



# Some Effects of Global Warming

**Species migration  
(shift) toward poles**

**140 million more climate refugees by 2050**

*~World Bank 2018*

**Extreme weather events have tripled in USA since 1970**

↑ Air pollution  
(↑ ozone in troposphere due to warmer temps.)

Increased frequency of weather extremes (storms/floods/droughts)

**Wet Areas Get Wetter, Dry Areas Drier**

**Loss of coastal land due to rising sea level**



**Increased forest & wild land fires**



**More unpredictable farming conditions in tropical areas**



**Longer growing seasons in cool areas**

**Dramatic changes in distribution and quantities of fish and sea foods**

**Malaria, Zika virus**



**Stronger Hurricanes**

## **Why We Need to Act Now**

- **Once CO<sub>2</sub> is dumped into atmosphere, 70% is still present after 100 years, 40% after 1,000 years**
- **Costs of climate change impacts are rising rapidly**
- **13 U.S. Federal Agencies issued climate report Nov. 2018 citing significant impacts to U.S Economy, health, & environment if steps aren't taken now to limit global warming**
- **IPCC OCT 2018 Special Report on Global Warming (Cites 6,000 research reports): Limiting global warming would avoid significant impacts & have clear benefits to natural ecosystems & people**
  - **Making emissions cuts now will cost money, but cheaper than paying for environmental, health, & economic costs, plus CO<sub>2</sub> removal later this century**
- **Stern Review on the Economics of Climate Change: Climate change could cost world 5–20% of GDP by 2200**
  - **Investing just 1% of GDP starting now could help to avoid many of these costs**



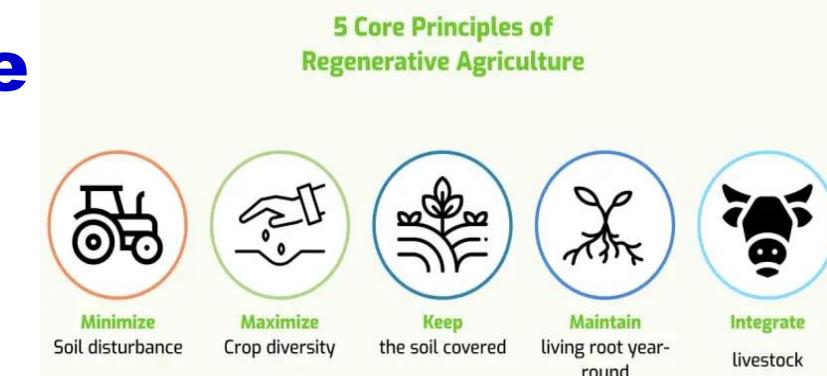
# We Can Respond in Two Ways: Mitigation, Adaptation

**1. Mitigation aims to alleviate or reduce the severity of climate change by:**

- Improving energy efficiency**
- Switching to clean and renewable energy sources**

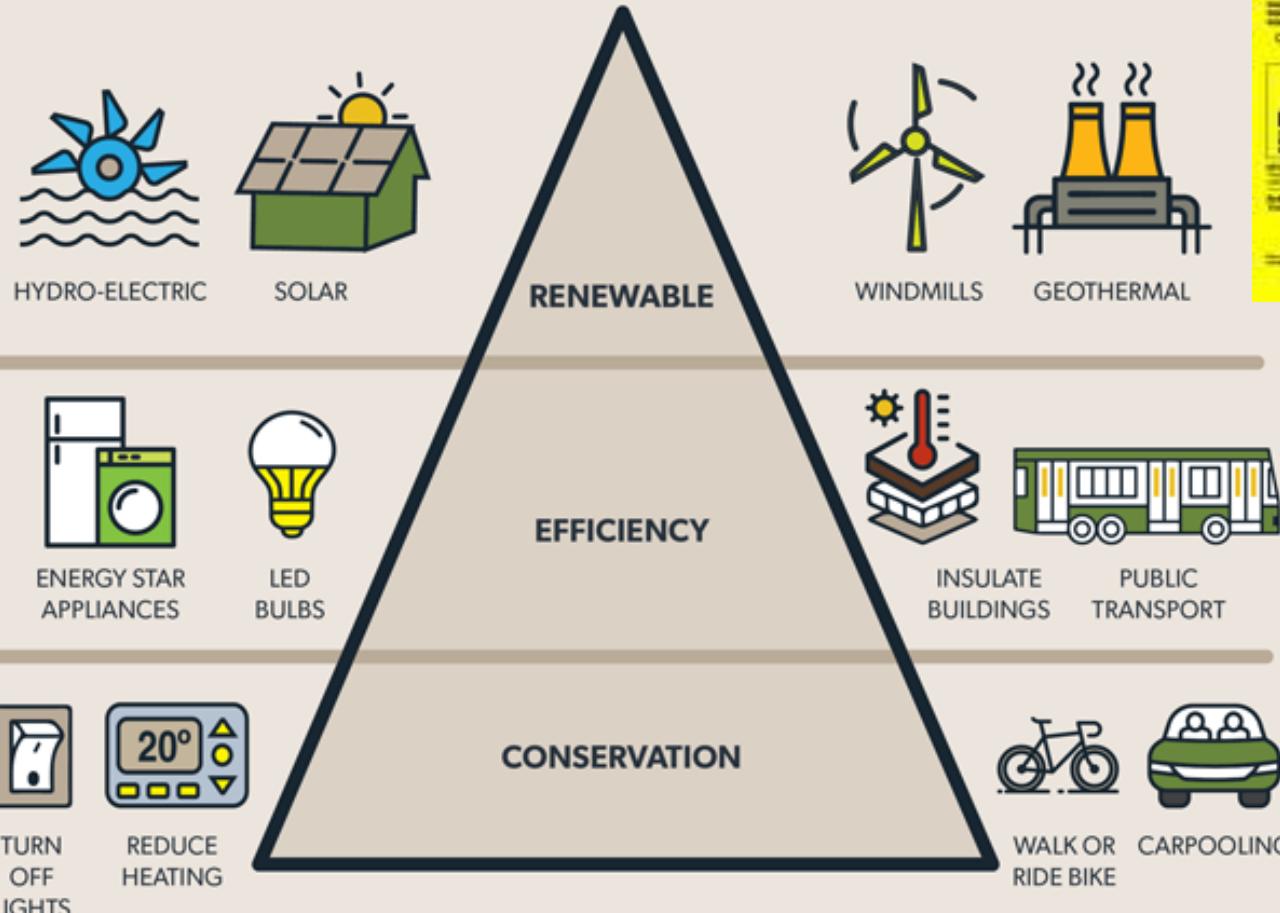


- Invest in Research & Development of green technology (solar, wind, wave, geothermal, biofuels, energy storage)**
- Preserving forests & wetlands (restoring too)**
- Recovering landfill gases**
  - Use to make electricity, or store underground**
- Protecting soil quality with regenerative & sustainable agriculture**
  - Healthy soil stores carbon absorbed by plants from atmosphere**



# Increase Green Energy & Efficiency + Conservation

## ENERGY SAVING



Fuel-efficient & zero emission vehicles



Efficient Appliances & Green Building Design

Mass Transit



# MAPPING OCEAN WEALTH

## COASTAL BLUE CARBON

Coastal wetlands – seagrass meadows, salt marshes and mangroves – provide one of the most effective natural solutions for carbon capture and long term storage on the planet.

Policymakers, industry and coastal practitioners should begin now to preserve and restore coastal wetlands because of their climate mitigation and market potential for the benefit of local communities and economies.

Mapping Ocean Wealth demonstrates what the ocean does for us today so that we maximize what the ocean can do for us tomorrow.

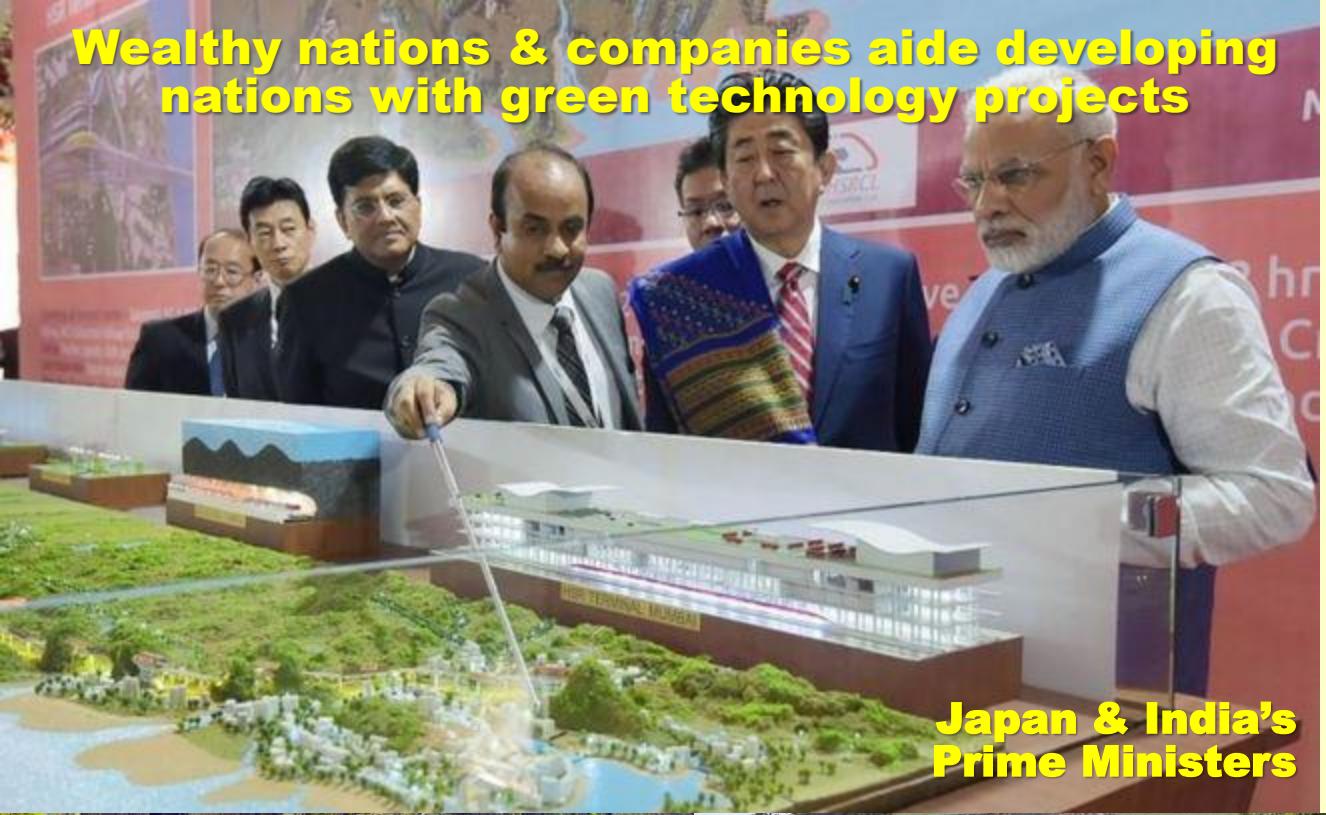
[oceanwealth.org](http://oceanwealth.org) @ocean\_wealth



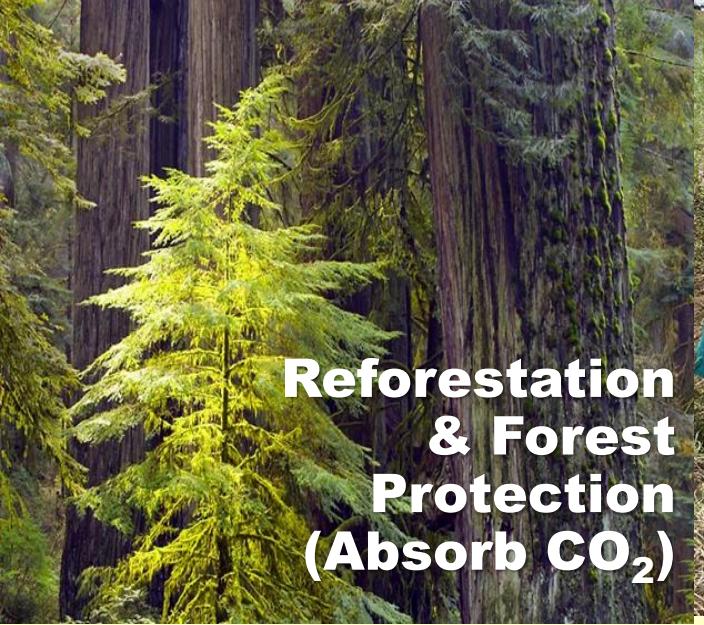
# Restoration of degraded ecosystems is critical



**Wealthy nations & companies aide developing nations with green technology projects**



**Japan & India's Prime Ministers**



**Reforestation & Forest Protection (Absorb CO<sub>2</sub>)**



**Unilever (Dutch Co.) plants one million trees in South Africa**

**Japan funds (\$17bn loan) the building of India's 1st high-speed train, cuts journey from 8 to 3 hours**



**STEM training for next generation of the green technology workforce**



# We Can Respond in Two Ways: Mitigation, Adaptation

## 2. Adaptation pursues strategies to cushion ourselves from the impacts of climate change

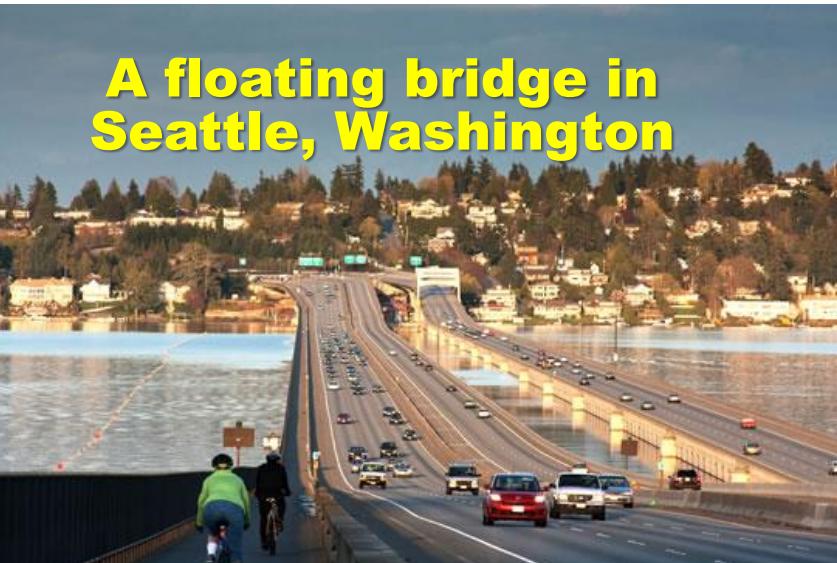
- Move to cities – easier to protect, produce fewer emissions per person
- More greenery in cities – shade + evaporation from plants reduces temperatures, paint dark surfaces white to reflect sunlight



Miami Beach is trying to adapt to sea level rise by constructing an elaborate system of pumps & drainage pipes

# Adaptation to Coastal Sea Level Rise

- **Restricting construction in at-risk areas**
- **Upgrading existing property**
- **Improving flood defenses**
- **Preparing for planned relocations**
  - **State of CA is planning >\$6 billion in sea level rise solutions (seawall improvements, flood mitigation for roads, wetland restoration & fortification)**



# Flood-Resistant Cities

**Wuhan, China is re-envisioning one of the world's largest parks to incorporate flooding as an essential element of the landscape**

**Similar designs  
could be  
incorporated  
along sea  
coasts**





## Restoring Natural Protection

**\$1 spent  
restoring  
mangroves,  
saves 5X more  
on damages  
than \$1 spent  
building a sea  
wall**

# What Can Each of Us Do?

- Everyone has a **carbon footprint** that expresses the amount of carbon we are responsible for emitting. This can be reduced by:
  - Choosing energy-efficient products & vehicles**
  - Eating fewer animal products, especially meat, eat local food**
  - Driving less, carpool, use mass transit**
  - Cutting back on waste, compost, use less plastic, switch to reusables**
  - Getting engaged politically**
  - Recycle, Buy recycled products**
  - Plant trees & gardens**
  - Don't idle car, proper tire inflation**
  - Unplug electronics**
  - Educate others**



How you get around.  
Walk, bike, or take mass transit instead of driving a car. If you drive, select a fuel-efficient vehicle, drive the speed limit, and keep your tires inflated.



How you power up.  
Promote efficiency by using energy-saving products. Encourage your institution to obtain energy from solar panels and water heaters, wind turbines, and ground-source heat pumps.



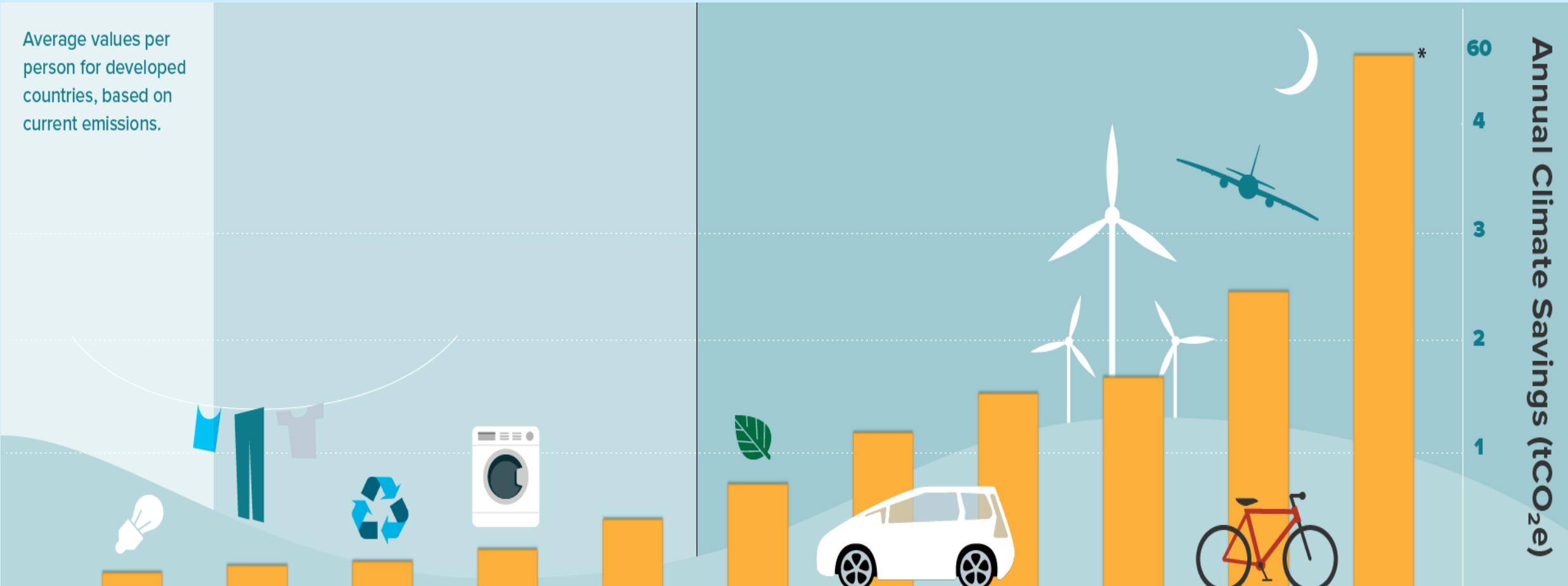
What you eat.  
Enjoy a plant-rich diet with fewer animal products, particularly carbon-intensive foods like beef. Waste less food and eat locally grown food.



What you do.  
Get involved in campus sustainability efforts, get engaged politically, or get trained for a green-collar job. Be a model for others by living a less wasteful, more sustainable lifestyle.

# Individual Actions to Reduce your Climate Change Impact

Average values per person for developed countries, based on current emissions.



**LOW IMPACT**

< 0.2 tCO<sub>2</sub>e

**MODERATE IMPACT**

0.2-0.08 tCO<sub>2</sub>e

**HIGH IMPACT**

> 0.8 tCO<sub>2</sub>e

\*Cumulative emissions from descendants; decreases substantially if national emissions decrease.

# Bio-Bus (Known as the Number 2)



**UK's 1<sup>st</sup> poo-powered bus  
Runs from Bath to Bristol airport – travels 186 miles on  
1 tank of biogas  
Biogas is made from human waste & food waste**

**Our past was  
built on coal  
& oil. Our  
future is being  
built on  
renewable  
energy**

# **People's Climate March**



# Living Sustainably

## **1. Reduce energy use:**

- Use mass transit, carpool, don't idle car, inflate tires, make your next car fuel efficient!**
- Unplug, turn down thermostat, use cold water**
- Support use of renewable energy**

## **2. Save water:**

- Don't run water & take shorter showers, install faucet aerators, low-flow shower heads & toilets; switch to drip irrigation & xeric landscaping**

## **3. Reduce, re-use, & recycle:**

- Bring your own bags & skip take-out, eat leftovers, donate unwanted items, use recycling bins, buy recycled products, buy products with less packaging**
- Recycle e-waste responsibly**

## Living Sustainably

### **4. Eat smart: Buy locally grown & organic foods**

- Eat lower on the food chain (less beef); purchase ethically raised meat, dairy, & eggs; buy sustainably harvested & farmed seafood; avoid products containing hormones & antibiotics**

### **5. Reduce chemical use: Use natural fertilizers & avoid pesticides in home gardens**

- Avoid bottled water & filter water at home, buy BPA-free containers & canned food**
- Use products made of natural materials & fragrances, make your own cleaning supplies (vinegar, lemon juice, baking soda, dish soap is all you need)**
- Reduce use of plastics – use glass, metal, etc.**

### **6. Educate yourself & others: knowledge is power**

# We are in Charge

If we love our planet, we need to protect it!  
Don't expect someone else to do the hard work  
Vote, speak truth to power, & never be afraid to share your knowledge. It truly is powerful!



Use  
Reusable  
bags



Carry your  
Hydroflask



**Now, Get  
Out There &  
See It!**

