

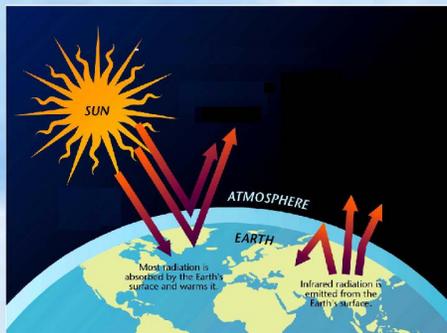
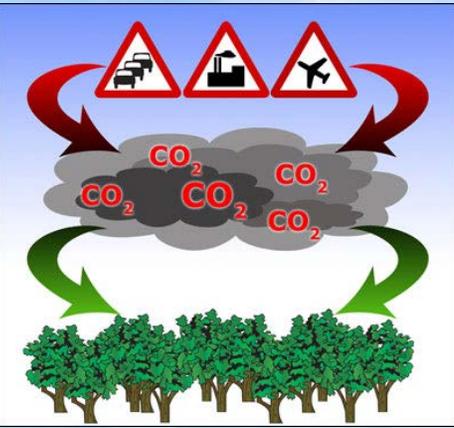


# Energy, Carbon Dioxide and Climate Change

Stephen E. Schwartz

**BROOKHAVEN**  
NATIONAL LABORATORY

Upton, Long Island, NY

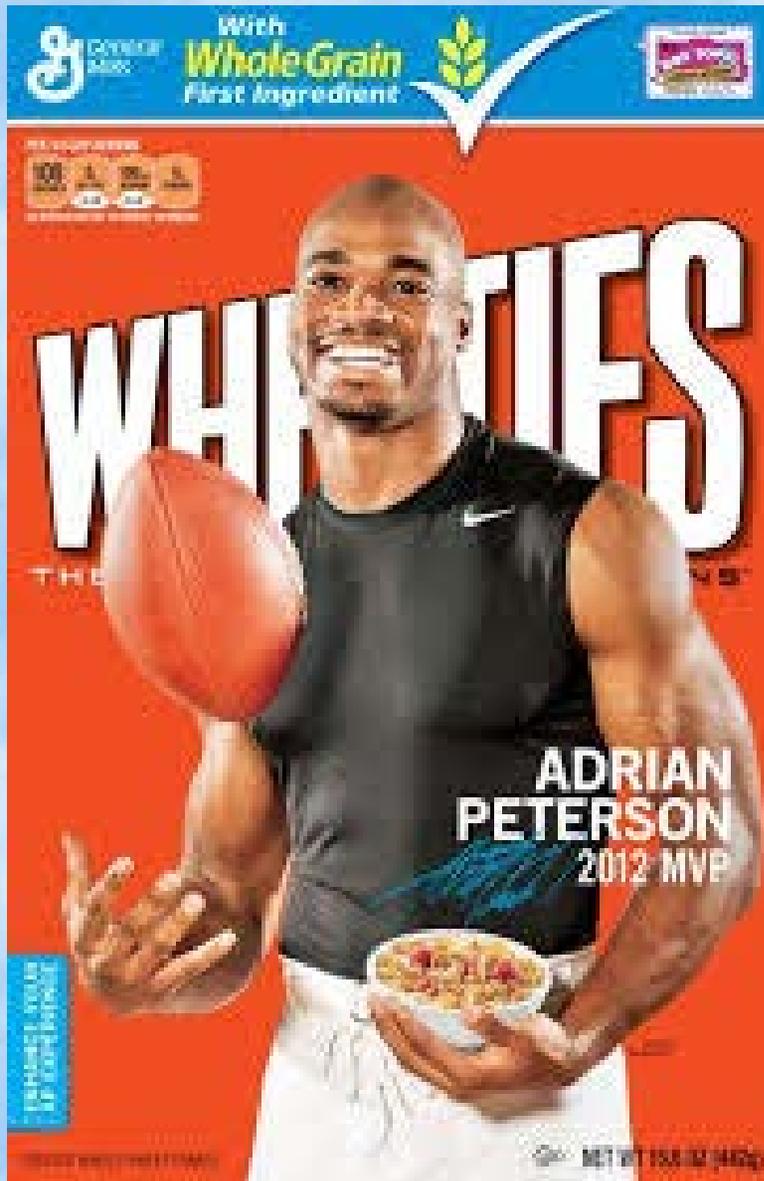


November 9, 2015

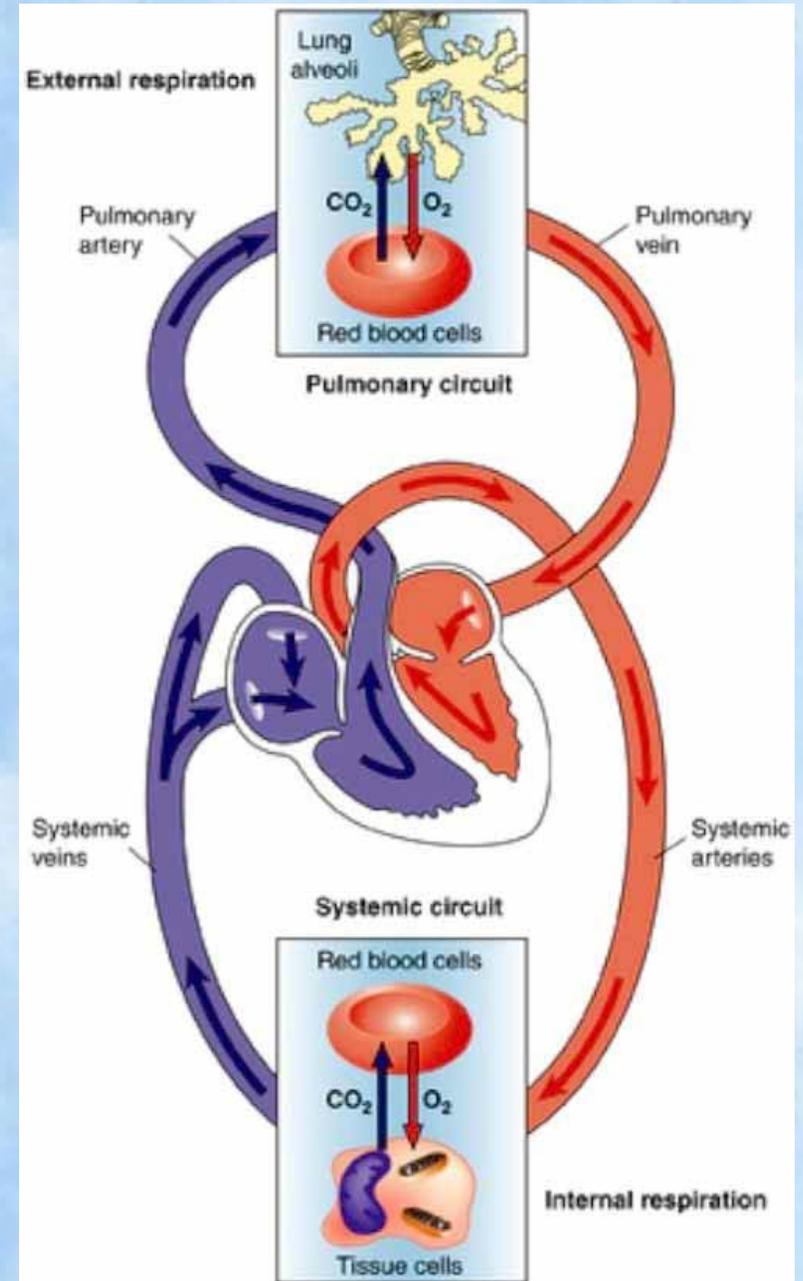
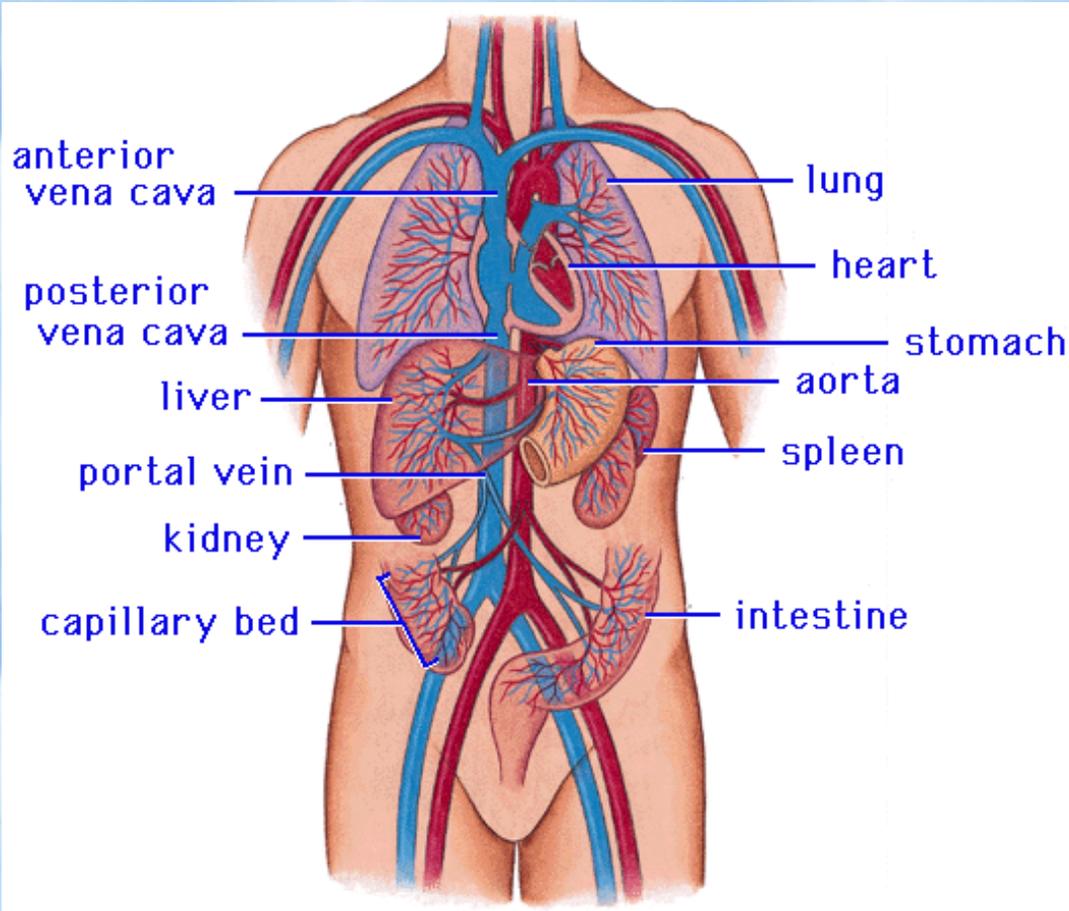
[www.ecd.bnl.gov/steve](http://www.ecd.bnl.gov/steve)



# WHERE DO YOU GET YOUR ENERGY?



# HOW DO ENERGY (AND OXYGEN) GET TO YOUR MUSCLES?



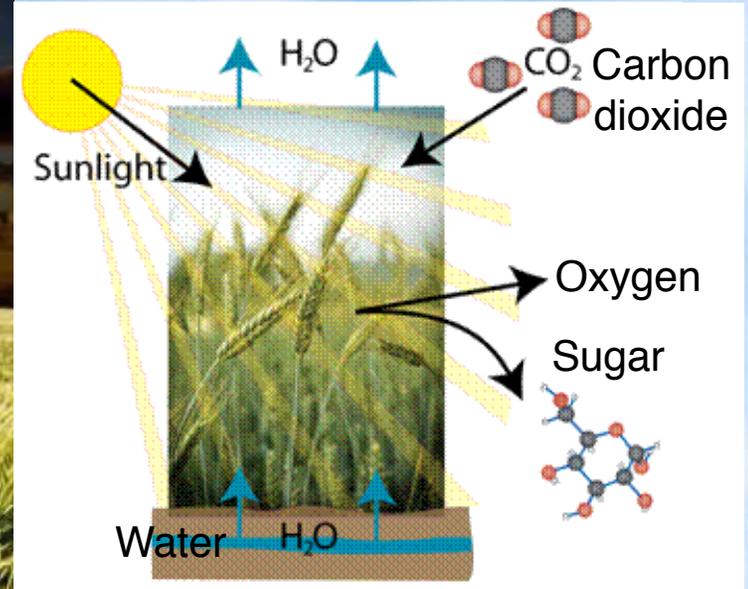
<http://library.thinkquest.org/5777/cir1.htm>

<http://newstt.com/how-is-circulatory-system-and-the-digestive-system-related/>

# WHERE DOES YOUR FOOD GET ITS ENERGY?



[www.desktopwallpaperhd.com](http://www.desktopwallpaperhd.com)



[www.ems.psu.edu/~pisupati/ACSO Outreach/Petroleum\\_1.html](http://www.ems.psu.edu/~pisupati/ACSO Outreach/Petroleum_1.html)

Food is stored solar energy.

HOW MUCH ENERGY  
IS IN YOUR FOOD?

# CALCULATE CALORIES PER GRAM



## Nutrition Facts

Serving Size 1 serving (30 g)

Per Serving

Calories 90

Calories from Fat 0

Total Fat 0g

Sodium 80mg

Potassium 5mg

Carbohydrates 70g

Sugars 53.3g

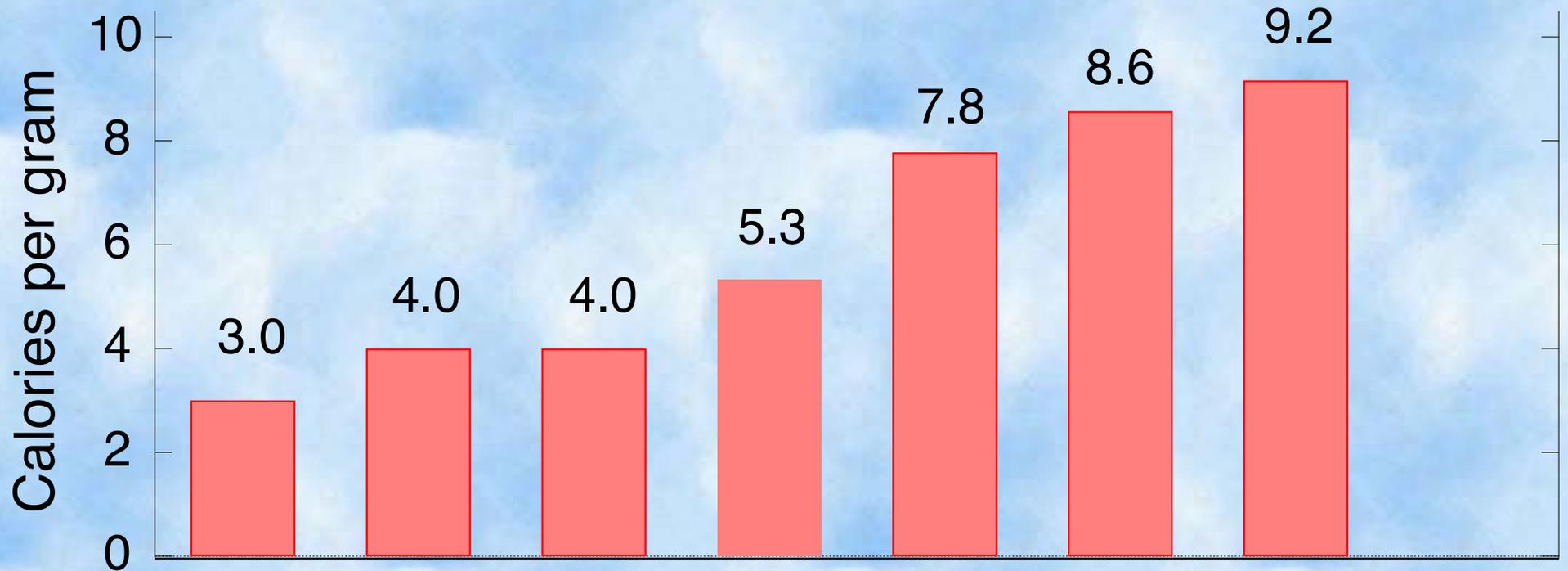
Protein 3.3g

90 Calories in 30 grams  
(about 1 ounce)

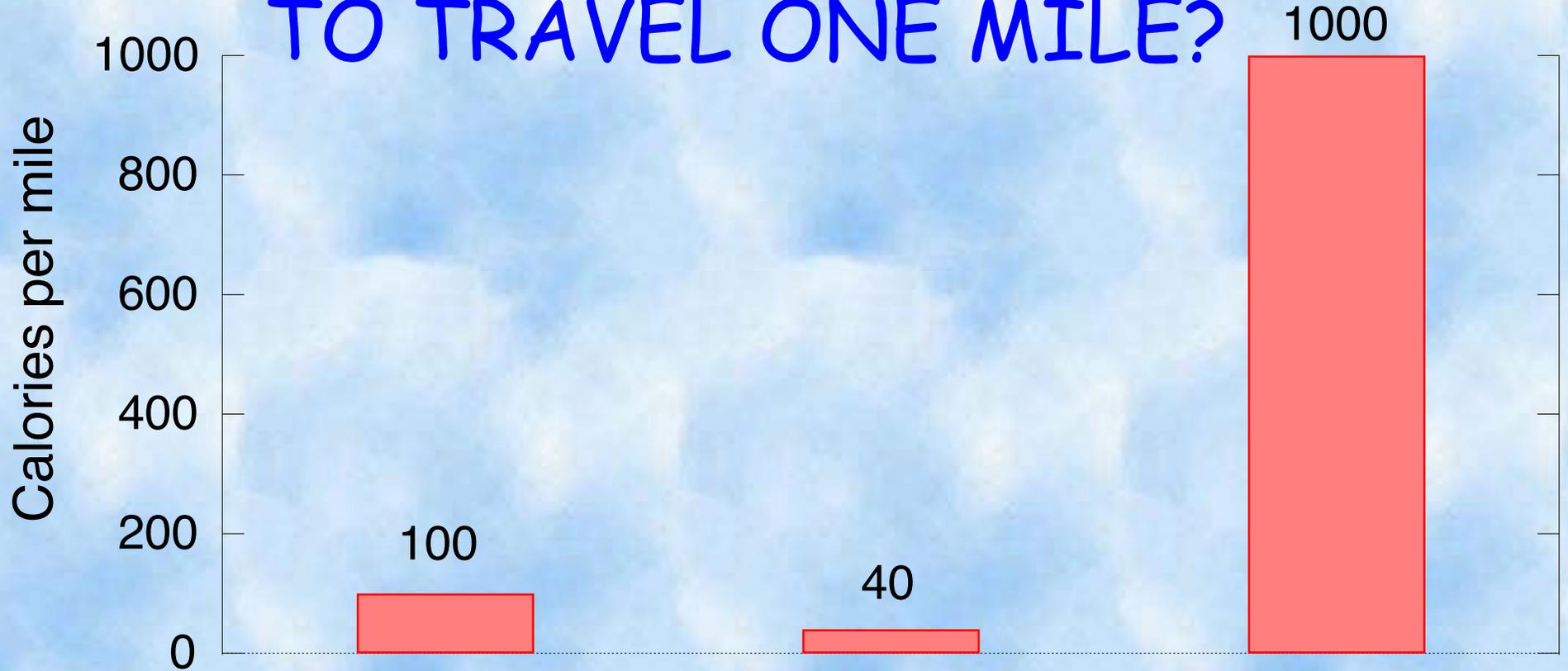
$$90 \div 30 = 3$$

3 Calories in one gram  
(3 Calories per gram)

# CALORIE CONTENT OF ENERGY FOODS



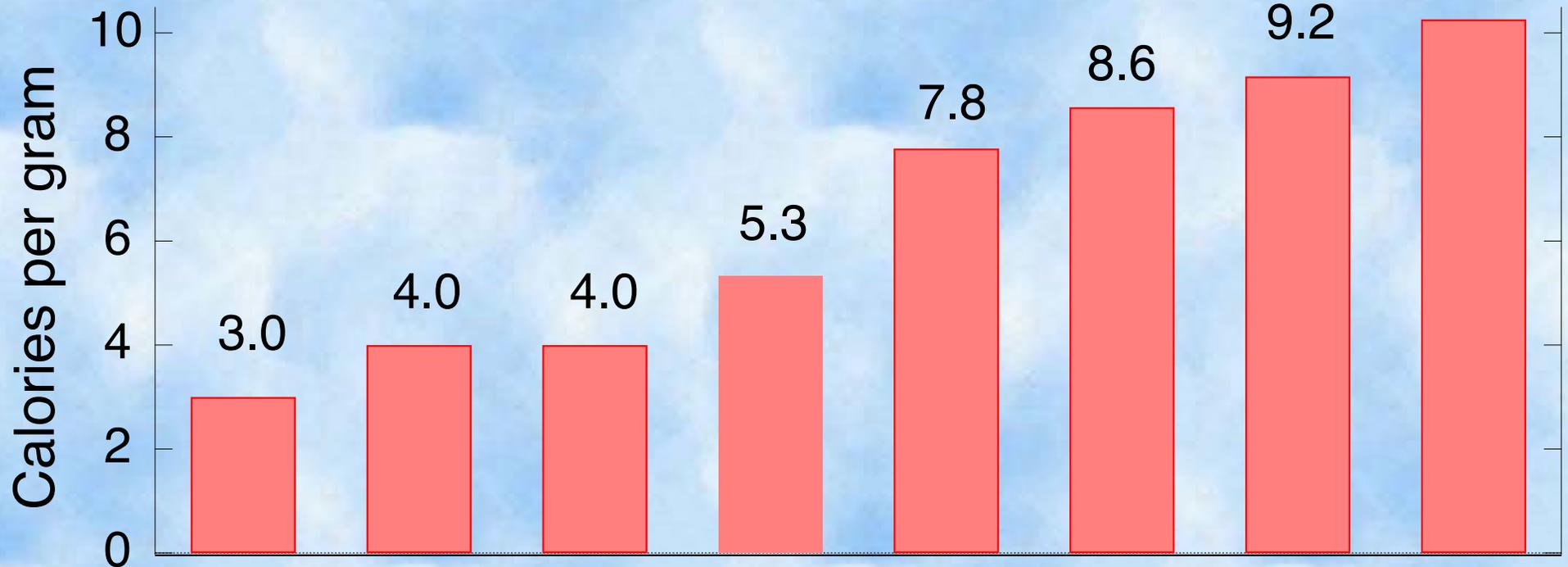
# HOW MUCH ENERGY DOES IT TAKE TO TRAVEL ONE MILE?



# WHERE DOES YOUR CAR GET ITS ENERGY?

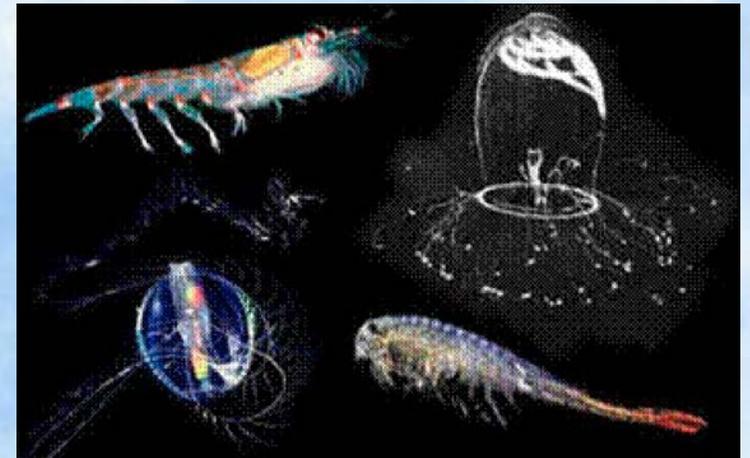
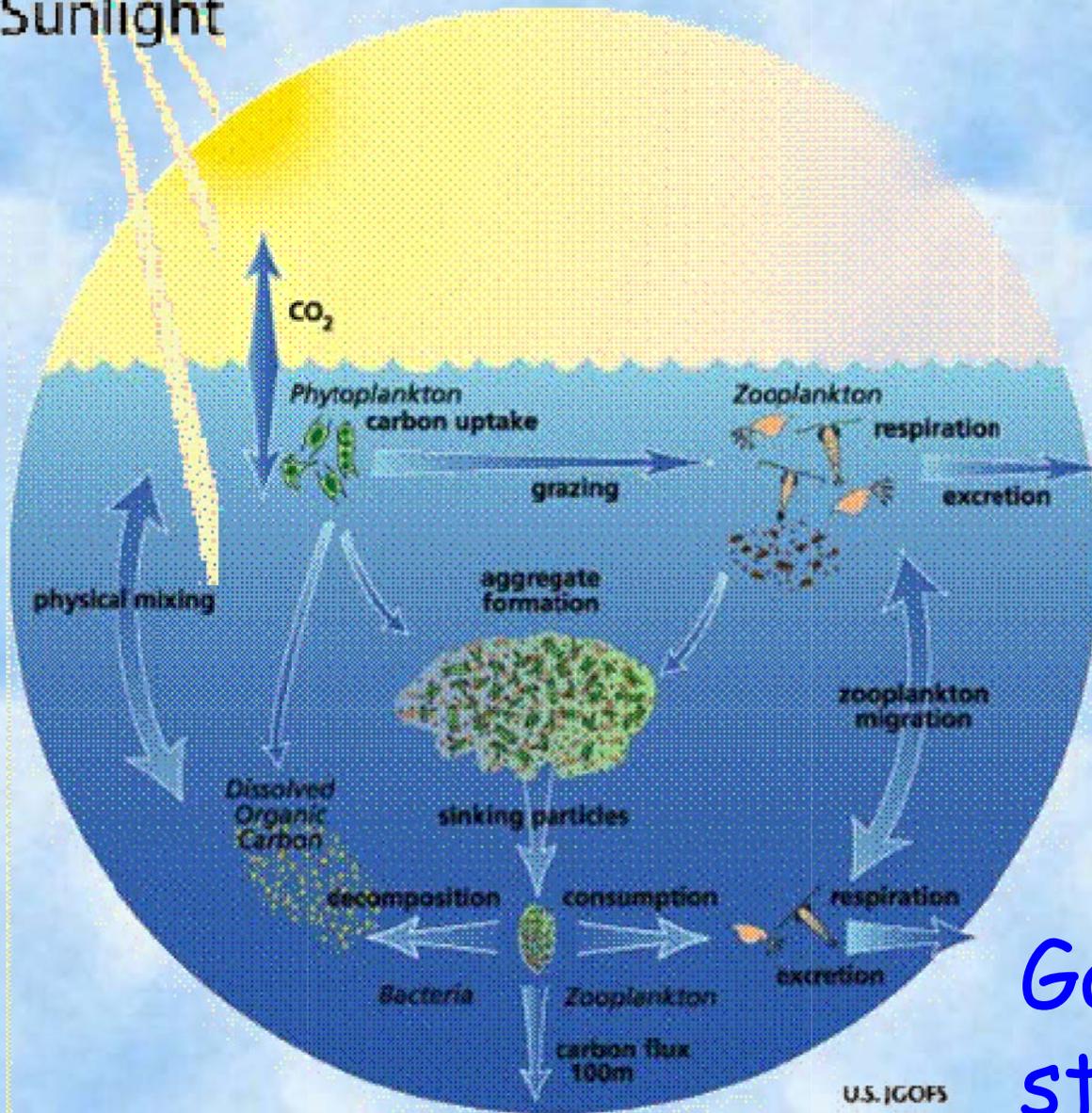


# CALORIE CONTENT OF ENERGY FOODS AND GASOLINE





# WHERE DOES GASOLINE GET ITS ENERGY?



Gasoline is also stored solar energy.

*We burn fossil carbon fuels to . . .*



*Heat our  
homes*

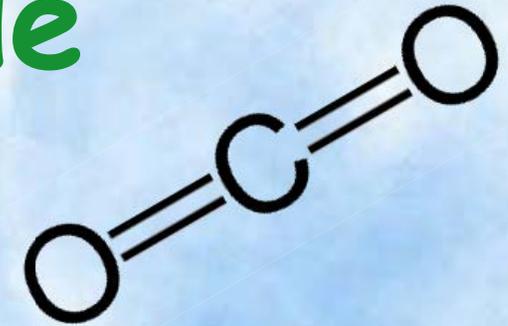
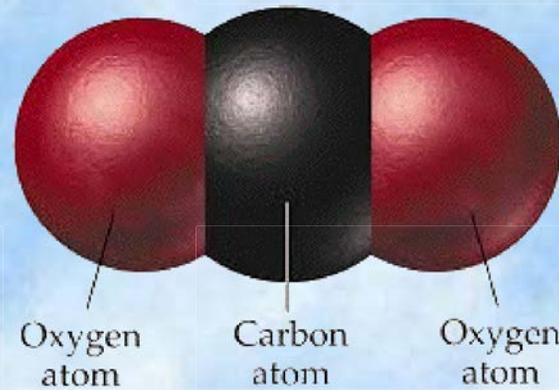
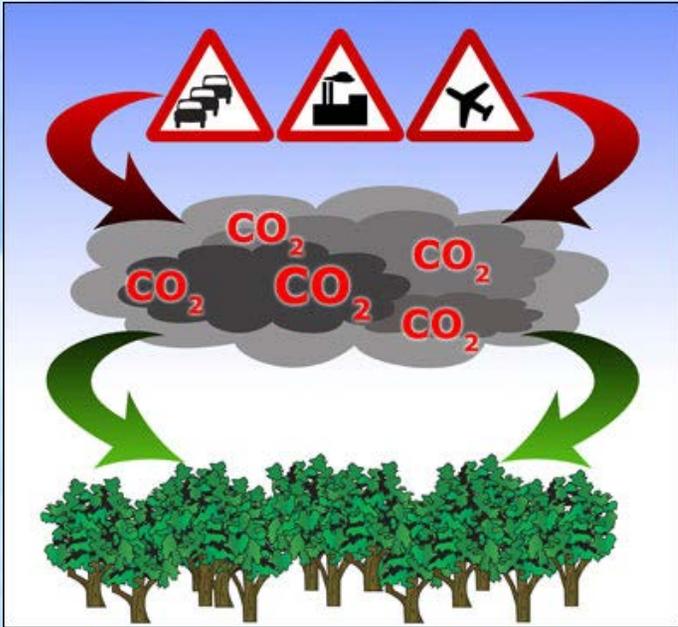


*Generate electric power*

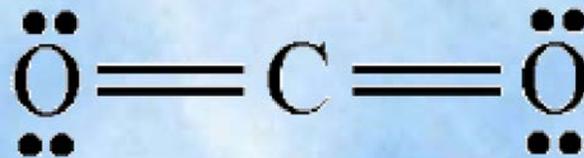
*Move goods and people  
from here to there*



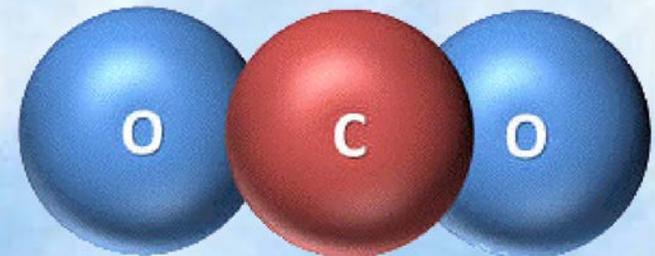
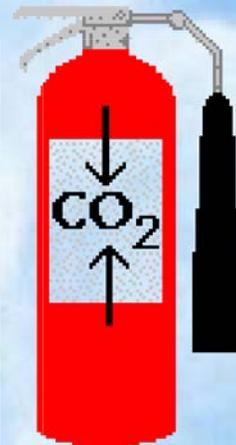
# Carbon Dioxide



**CAUTION**  
**CARBON**  
**DIOXIDE**

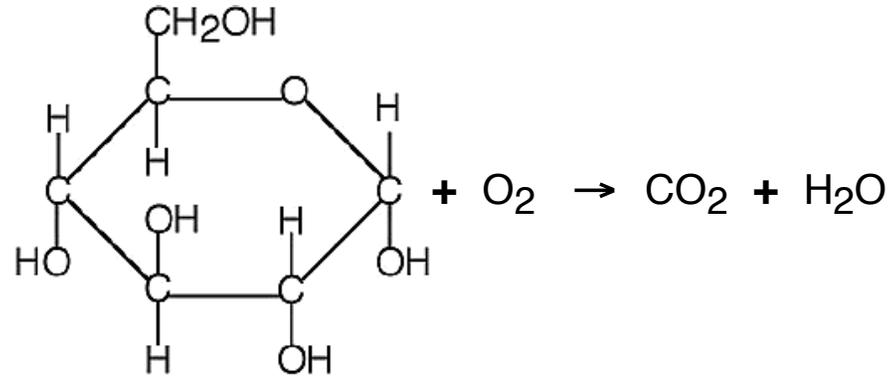


**DANGER**  
**CARBON**  
**DIOXIDE**

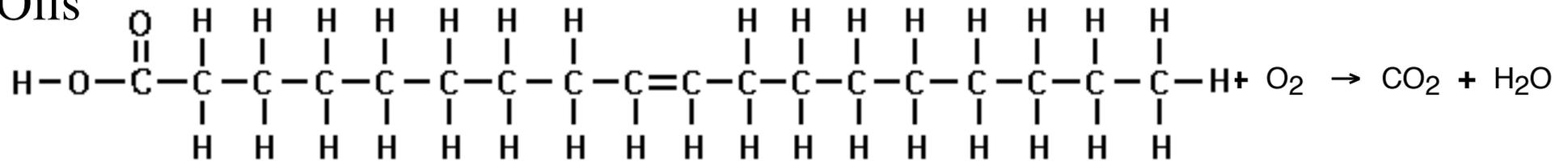


*We get energy by oxidizing carbon compounds.*

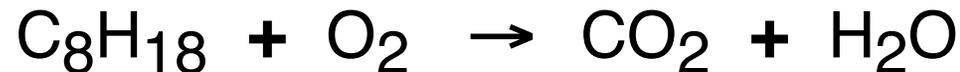
Sugars



Oils



Gasoline



We convert chemical energy to heat and mechanical energy by bringing carbon to a thermodynamic state of lower energy.

But all these reactions produce *carbon dioxide* as a by-product.

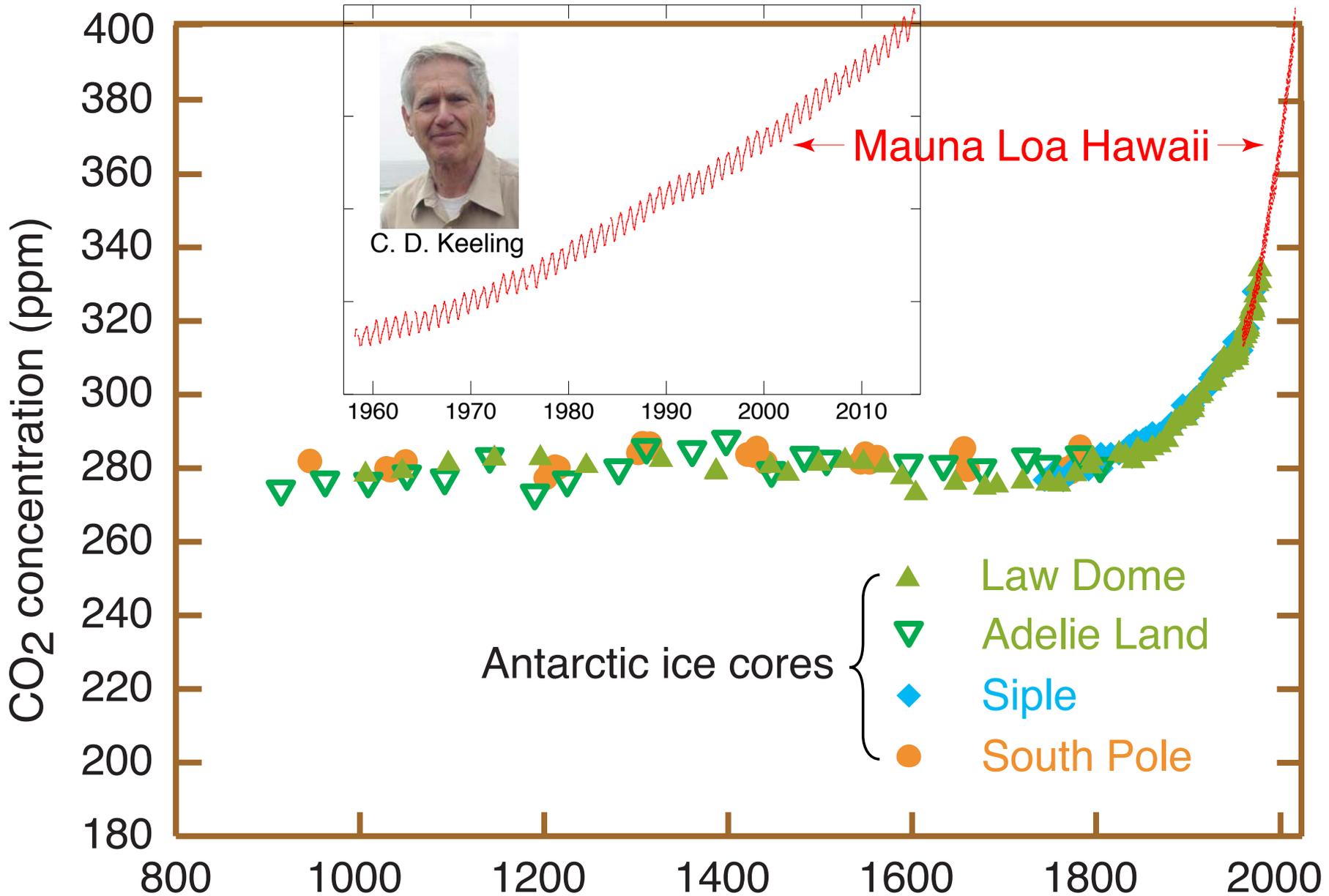
# GLACIERS ARE OUR TIME MACHINE



*New York Times, July 2, 2012*

Lonnie Thompson, Ohio State University glaciologist, studies Earth's climate history by the ice archive.

# ATMOSPHERIC CARBON DIOXIDE IS INCREASING



Global carbon dioxide concentration over the last thousand years

***WHERE IS ALL  
THIS CO<sub>2</sub>  
COMING FROM?***

***WHO IS  
RESPONSIBLE?***



# HOW MUCH CARBON IS IN A GALLON OF GASOLINE?



1 lb?

3 lbs!?



2 lbs?

5 lbs!?!?



All of this carbon goes into the atmosphere as carbon dioxide when you burn the gasoline in your car.

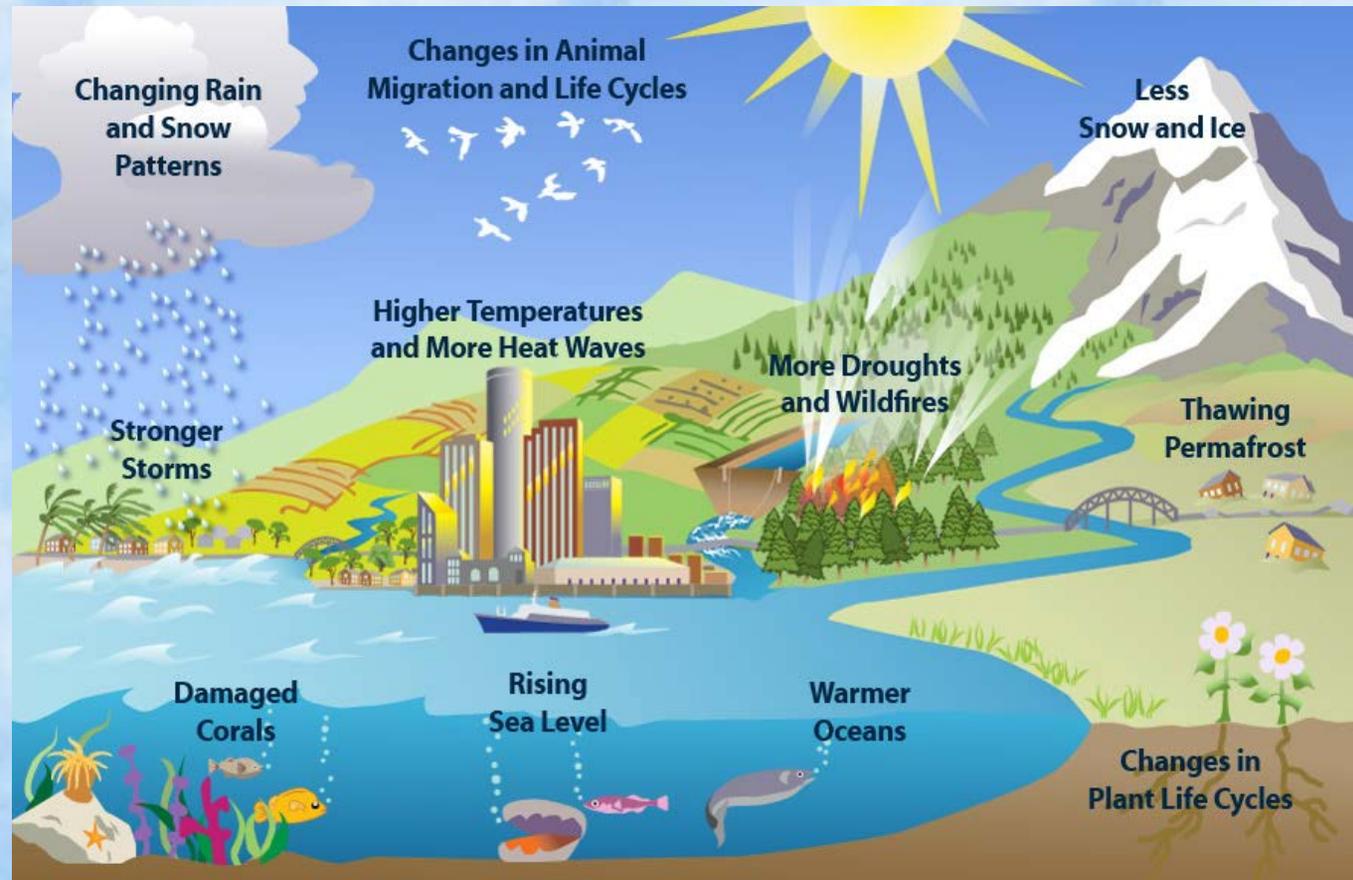
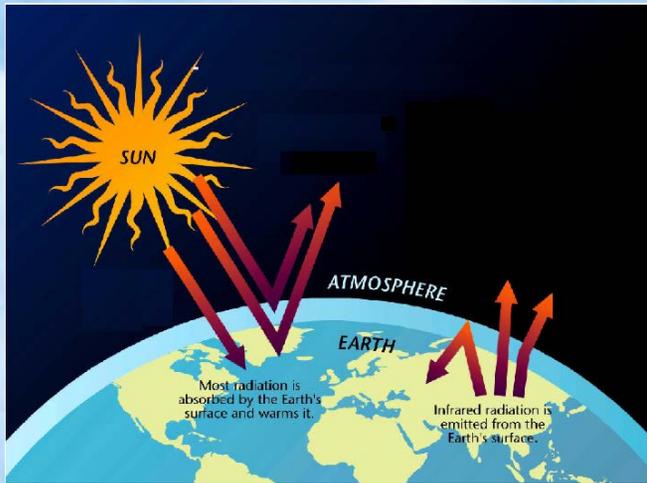


There's one law that even the Congress of the United States can't repeal . . .

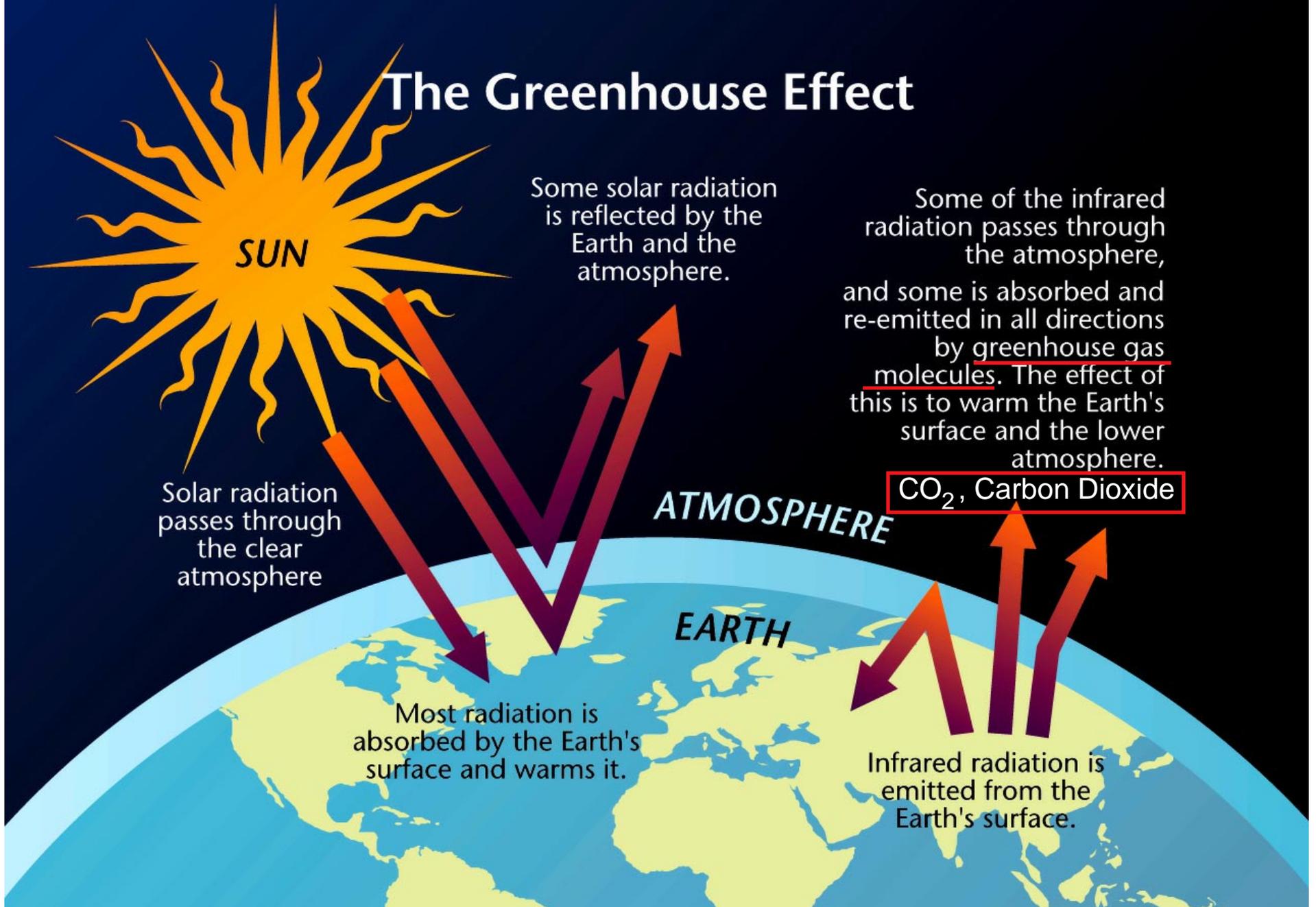


The law of conservation of matter.

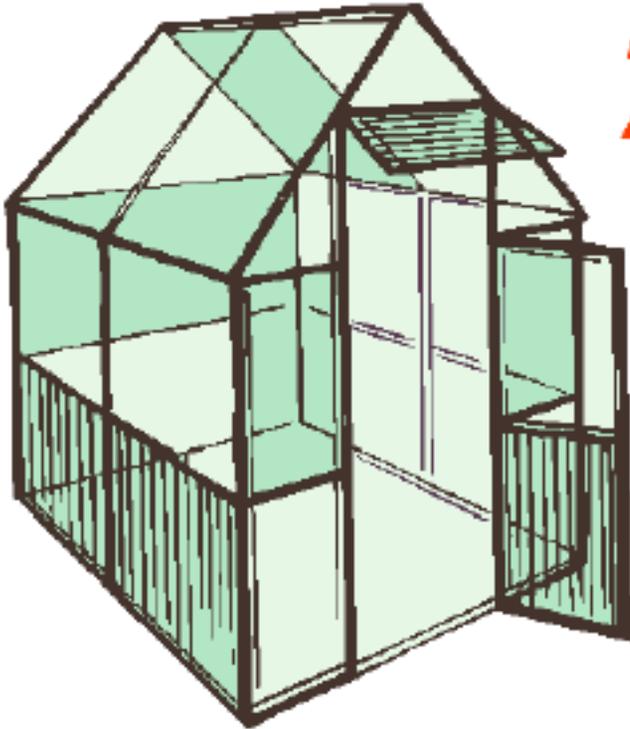
# The Greenhouse Effect, Climate, and Climate Change



# The Greenhouse Effect



# THE GREENHOUSE EFFECT



## *EARTH'S ENERGY BUDGET: A DELICATE BALANCE*

- Sunlight heats the Earth.
- The warm Earth radiates energy (in the form of infrared radiation, or heat) back out to space.
- Some of this infrared radiation is trapped in the atmosphere, giving Earth its temperate climate.

**This is the greenhouse effect.**

Global average temperature 15°C or 59°F

Without it, the Earth's climate would be like the moon's, harsh and severe.

Global average temperature -19°C or -2 °F

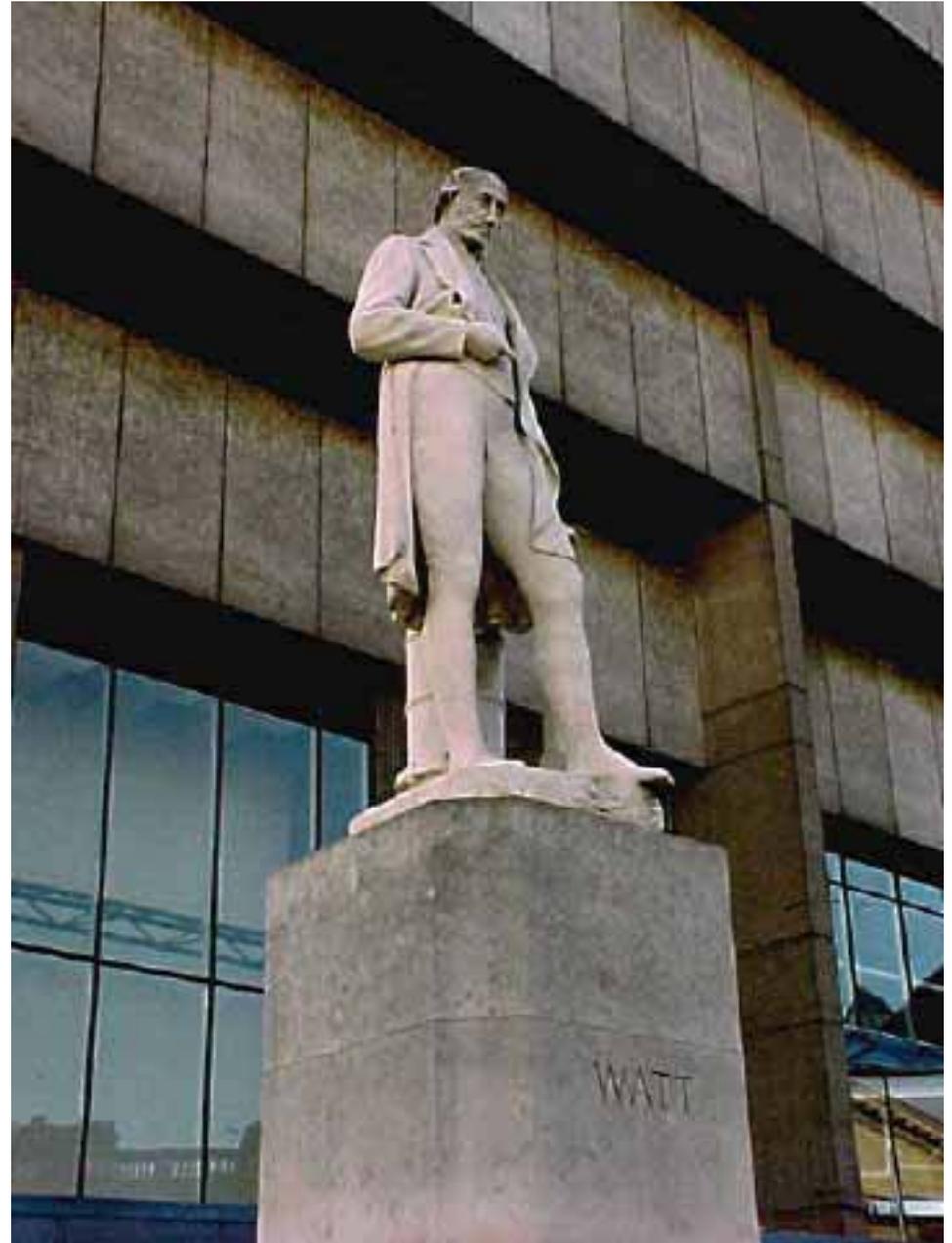
# ***ATMOSPHERIC RADIATION***

*Power per area*

*Unit:*

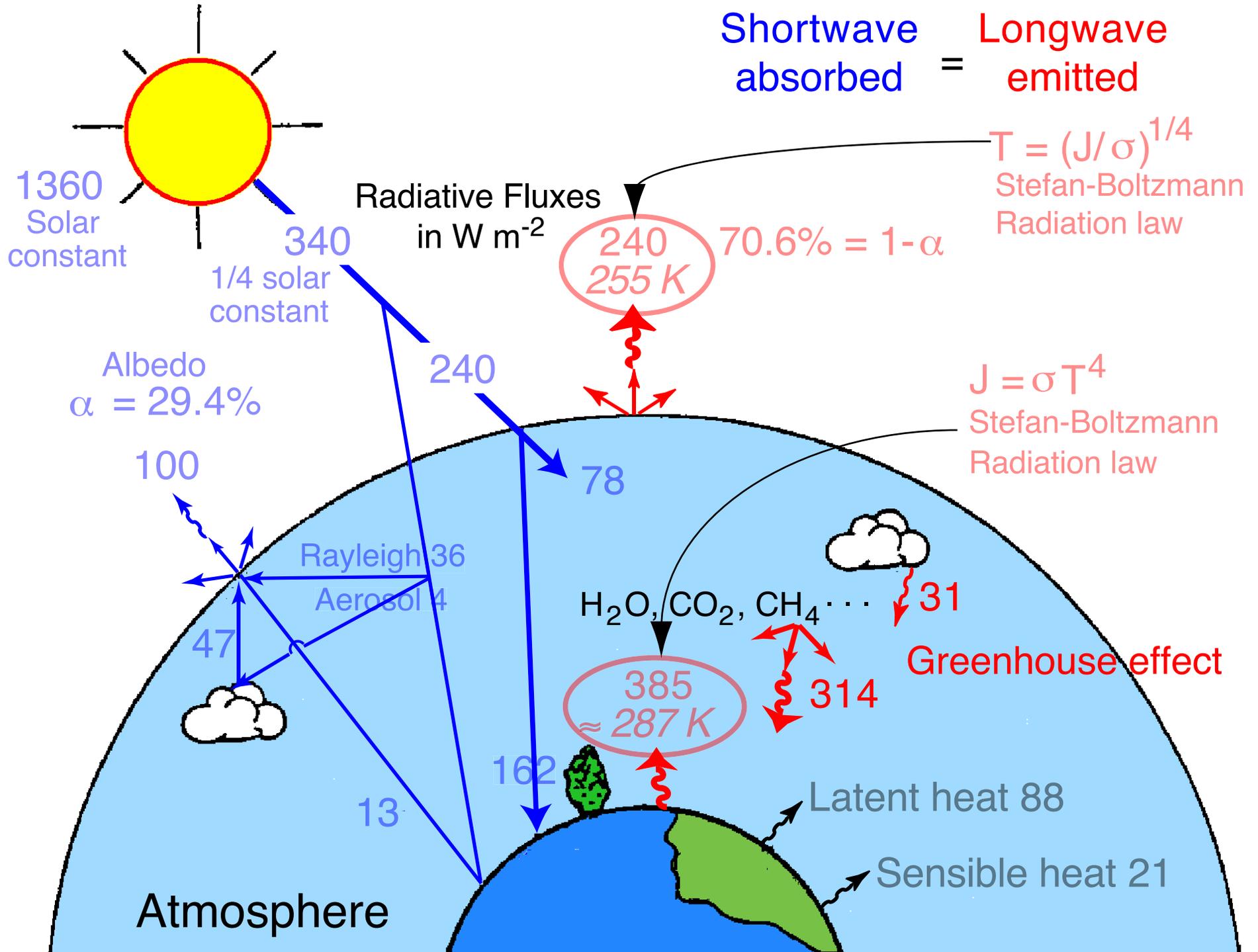
*Watt per square meter*

*$W m^{-2}$*

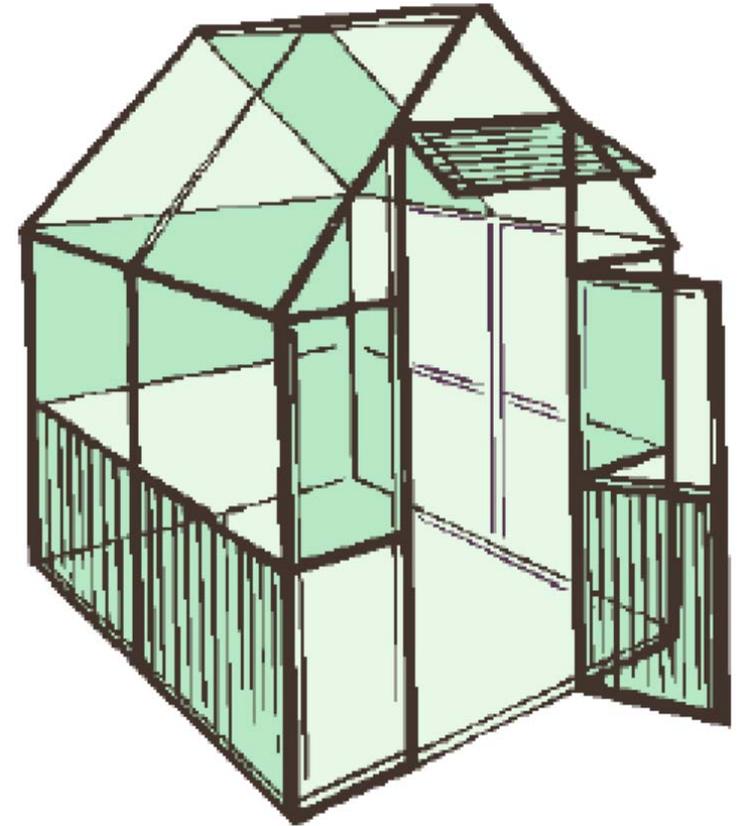
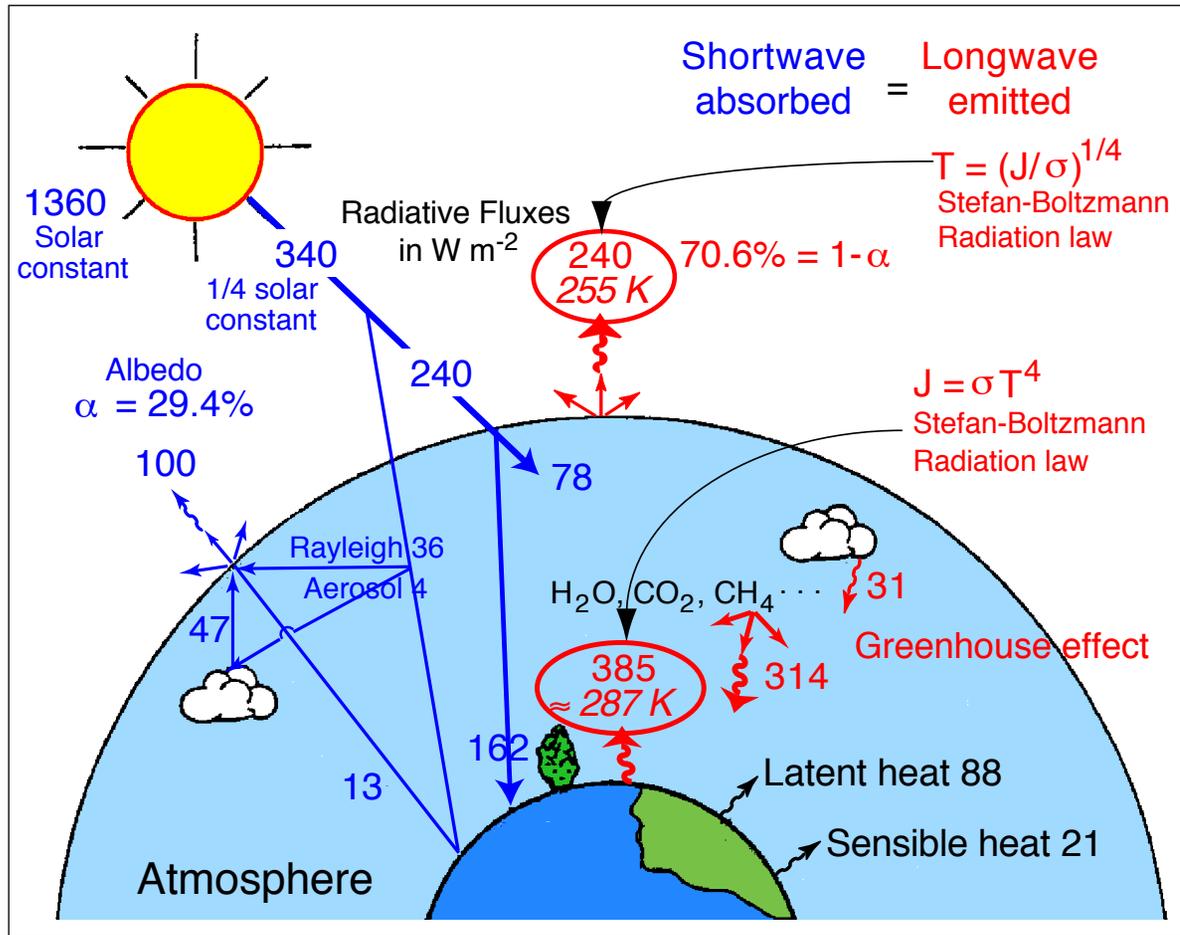


*Photo: S. E. Schwartz*

# EARTH'S RADIATION BUDGET AND THE GREENHOUSE EFFECT



# EARTH'S RADIATION BUDGET AND THE GREENHOUSE EFFECT

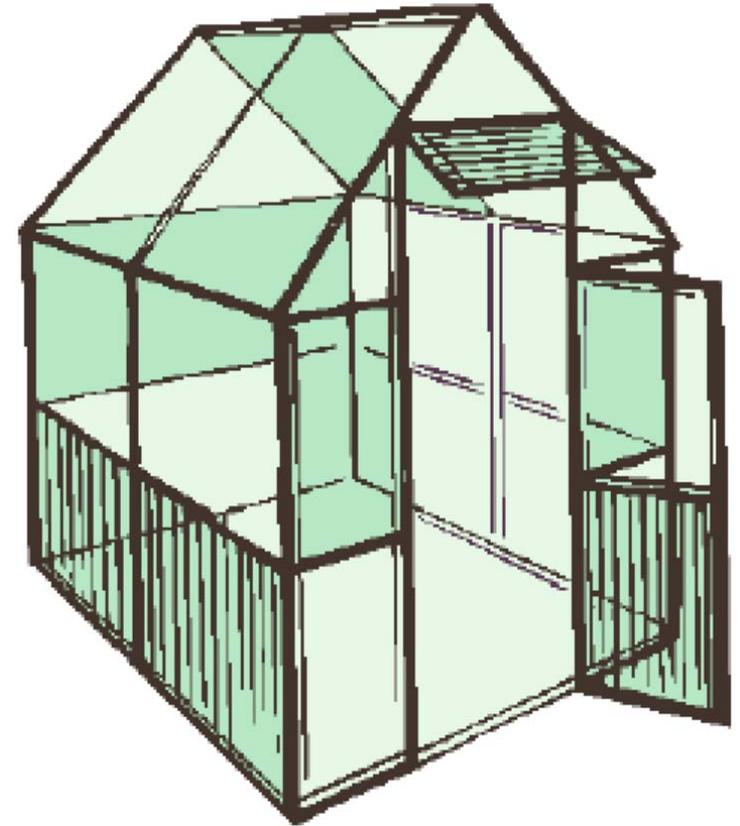
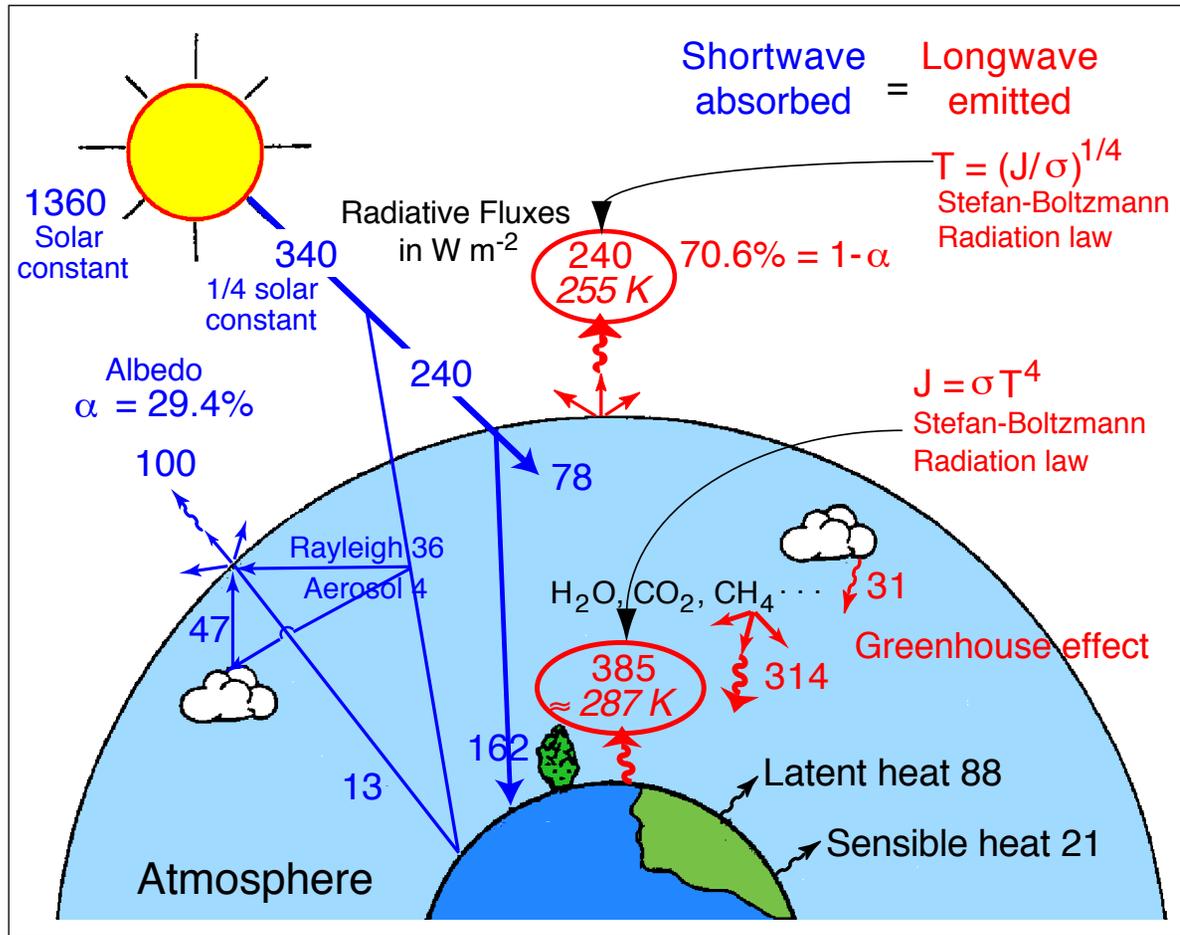


*To summarize:*

The greenhouse effect maintains Earth's surface temperature about 32 °C warmer than it would otherwise be.

The greenhouse effect is responsible for Earth's temperate climate.

# EARTH'S RADIATION BUDGET AND THE GREENHOUSE EFFECT



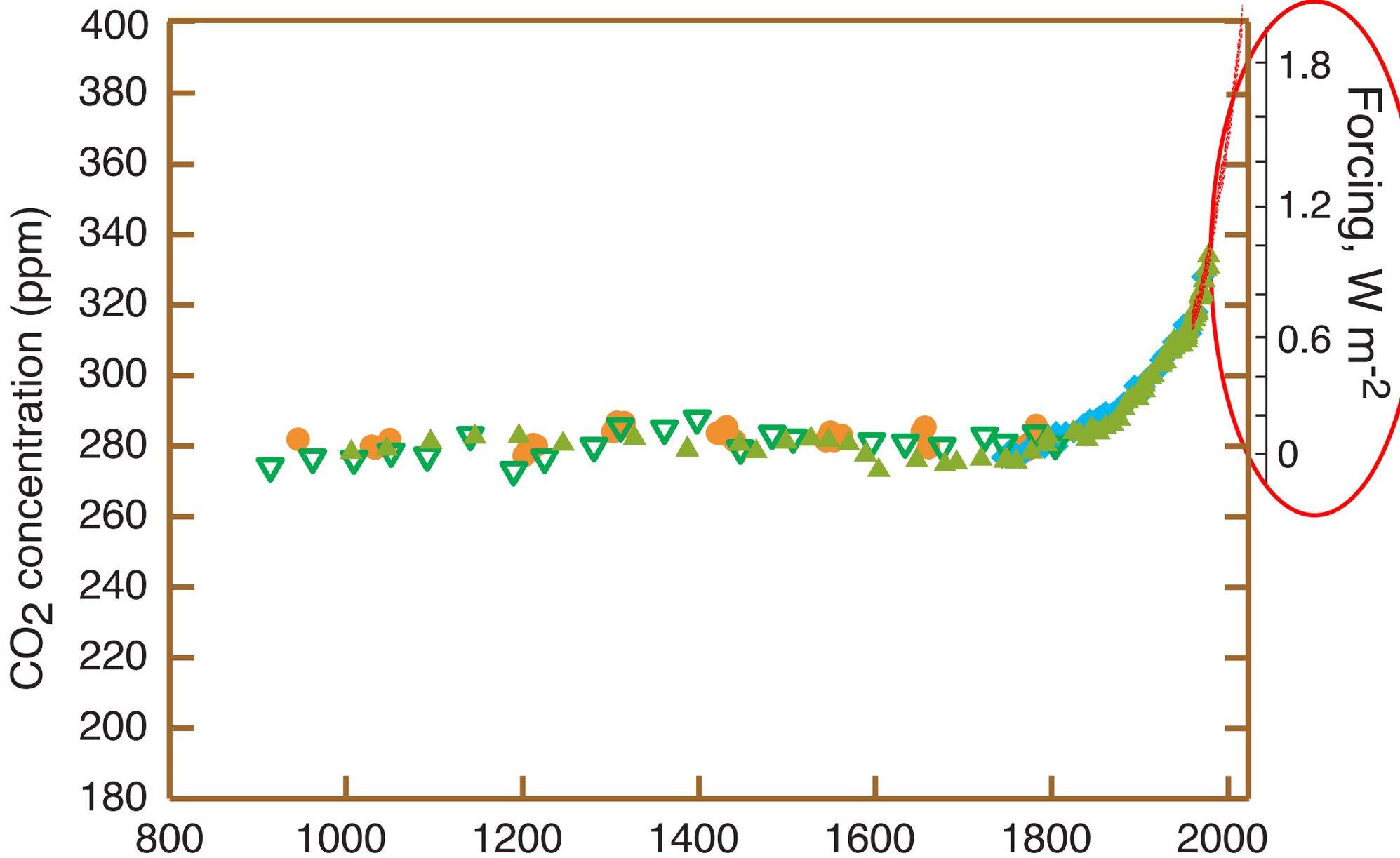
***To summarize:***

The greenhouse effect maintains Earth's surface temperature about 32 °C warmer than it would otherwise be.

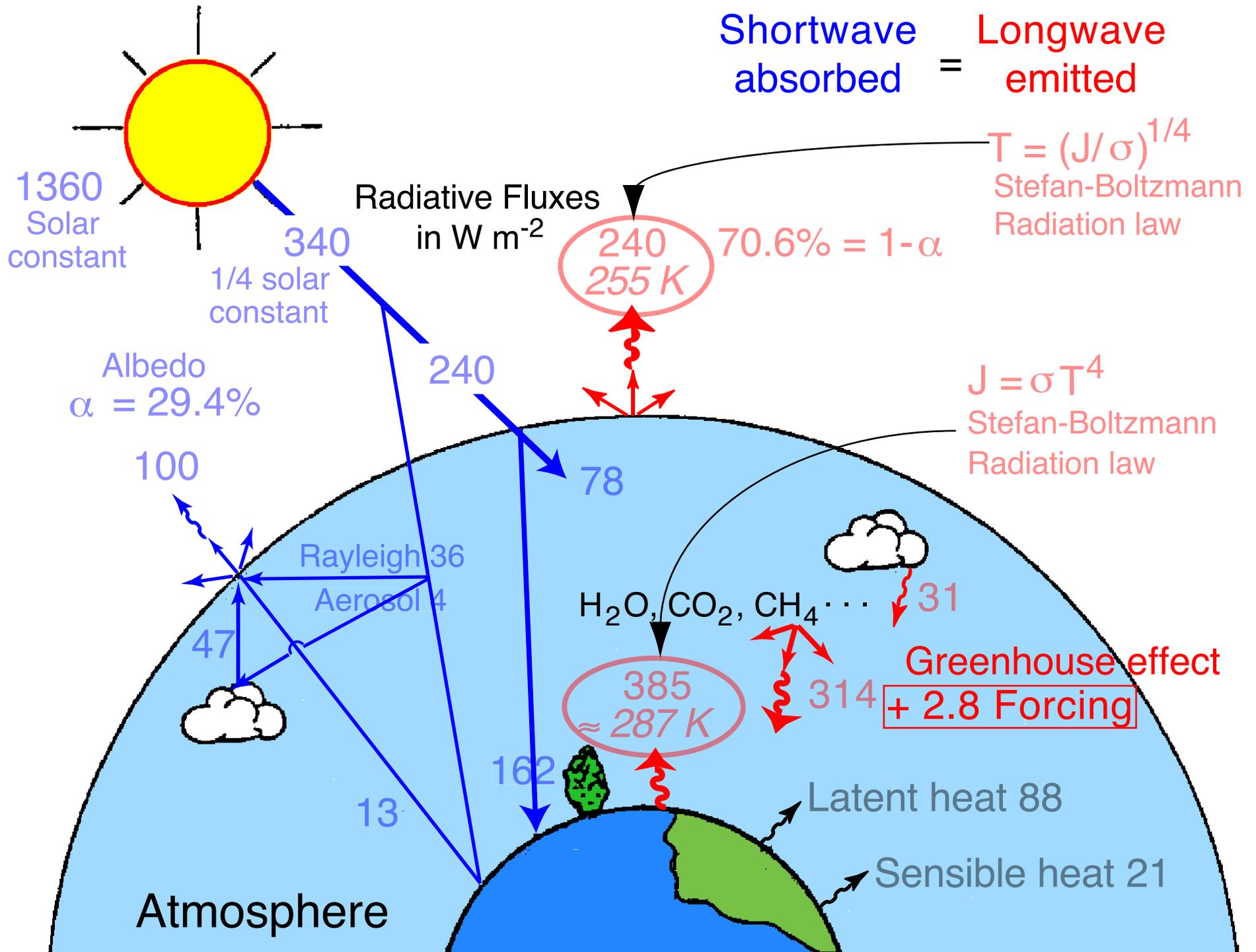
The greenhouse effect is responsible for Earth's temperate climate.

But, can there be too much of a good thing?

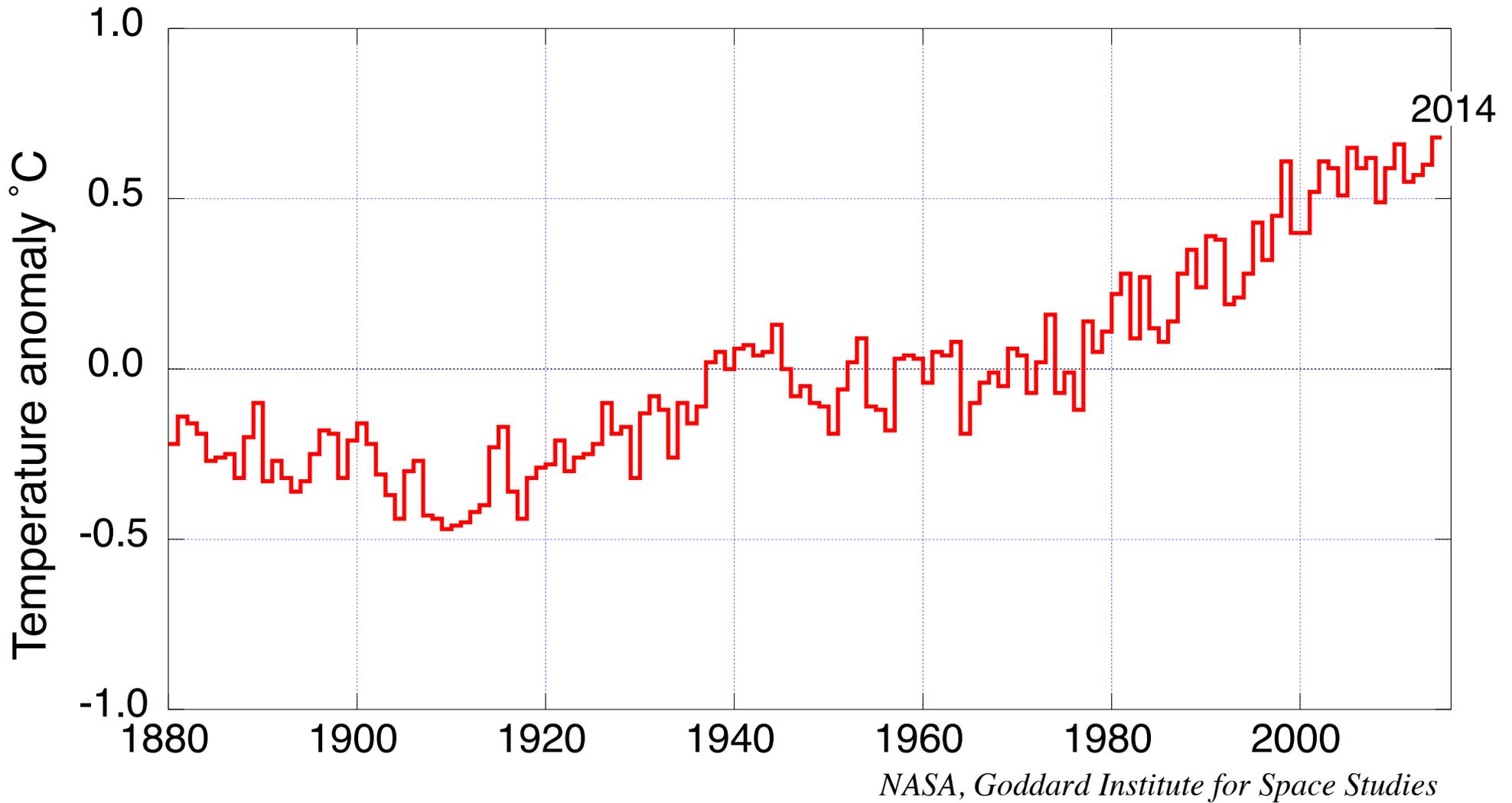
# RADIATIVE FORCING BY CARBON DIOXIDE



# EARTH'S RADIATION BUDGET AND THE GREENHOUSE EFFECT



# GLOBAL TEMPERATURE CHANGE SINCE 1880

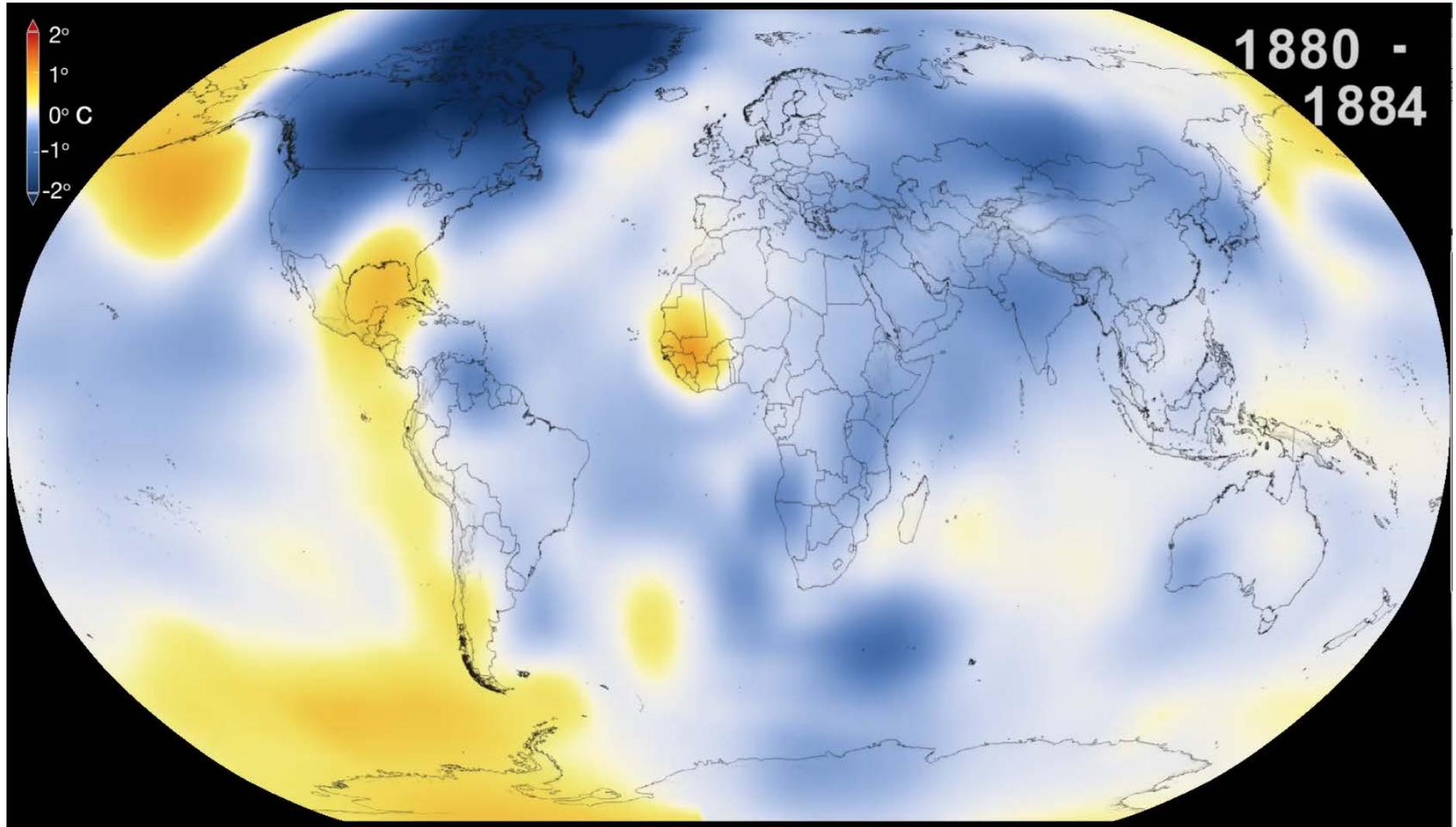


2014 was the hottest year on record.

14 of the hottest 15 years have been since 2000.

# THE WARMING PLANET

Five-Year-Average Temperature Anomalies Relative to Mid 20<sup>th</sup> Century

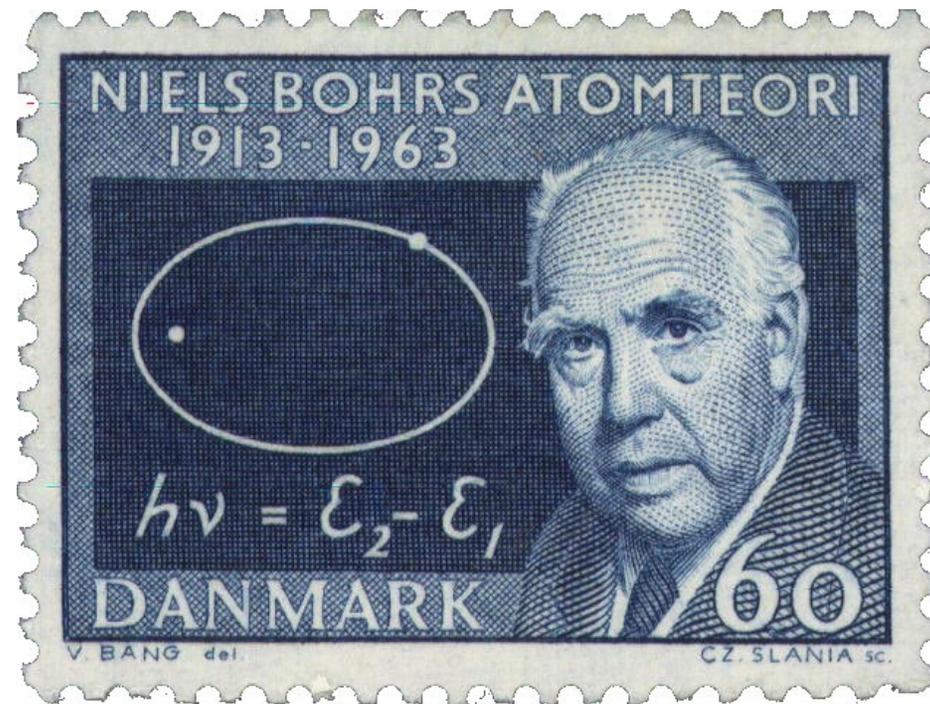


*NASA Goddard Institute for Space Studies*

*Looking to the  
Future . . .*



*Prediction is difficult,  
especially about the future.*



*– Niels Bohr*

# THE BIBLE OF CLIMATE CHANGE

*It's big and thick.*

*Every household should have one.*

*No one reads it from cover to cover.*

*You can open it up on any page  
and find something interesting.*

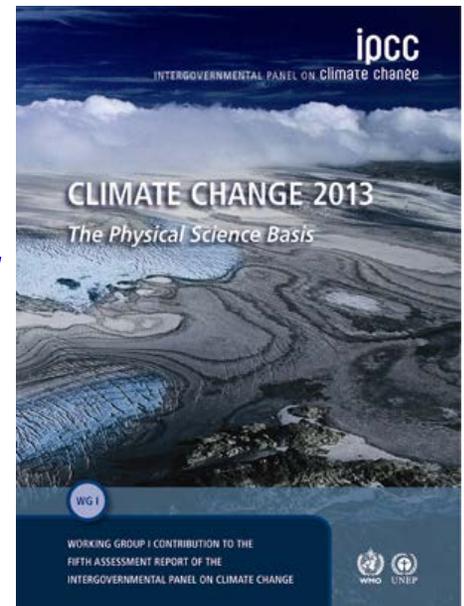
*It was written by a committee.*

*It is full of internal contradictions.*

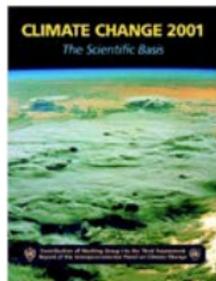
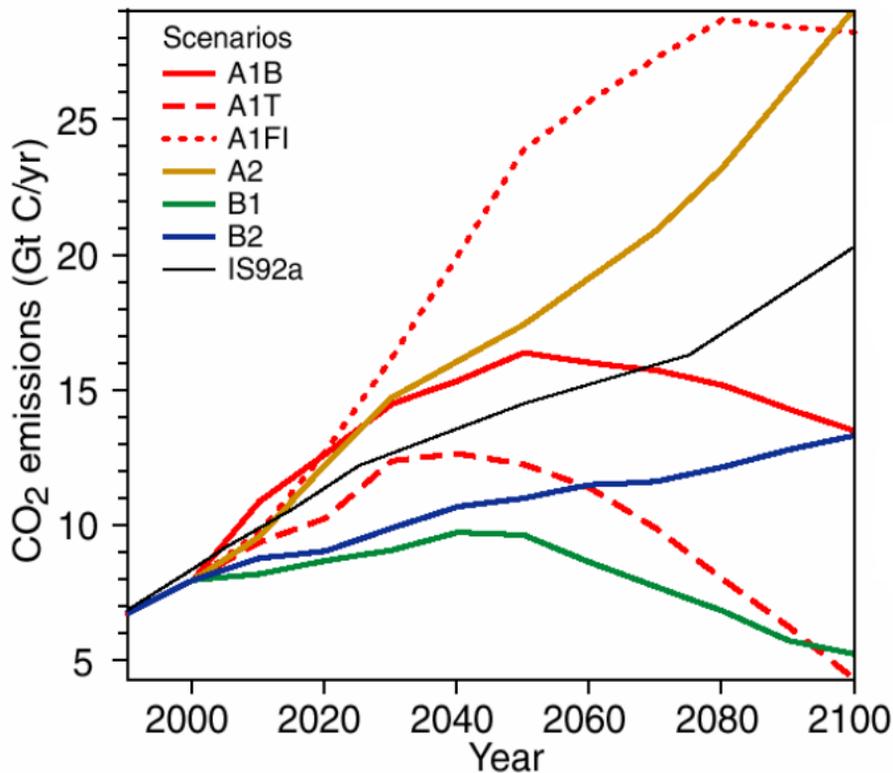
*It deals with cataclysmic events such as  
floods and droughts.*

*It has its true believers and its skeptics.*

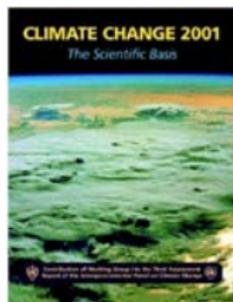
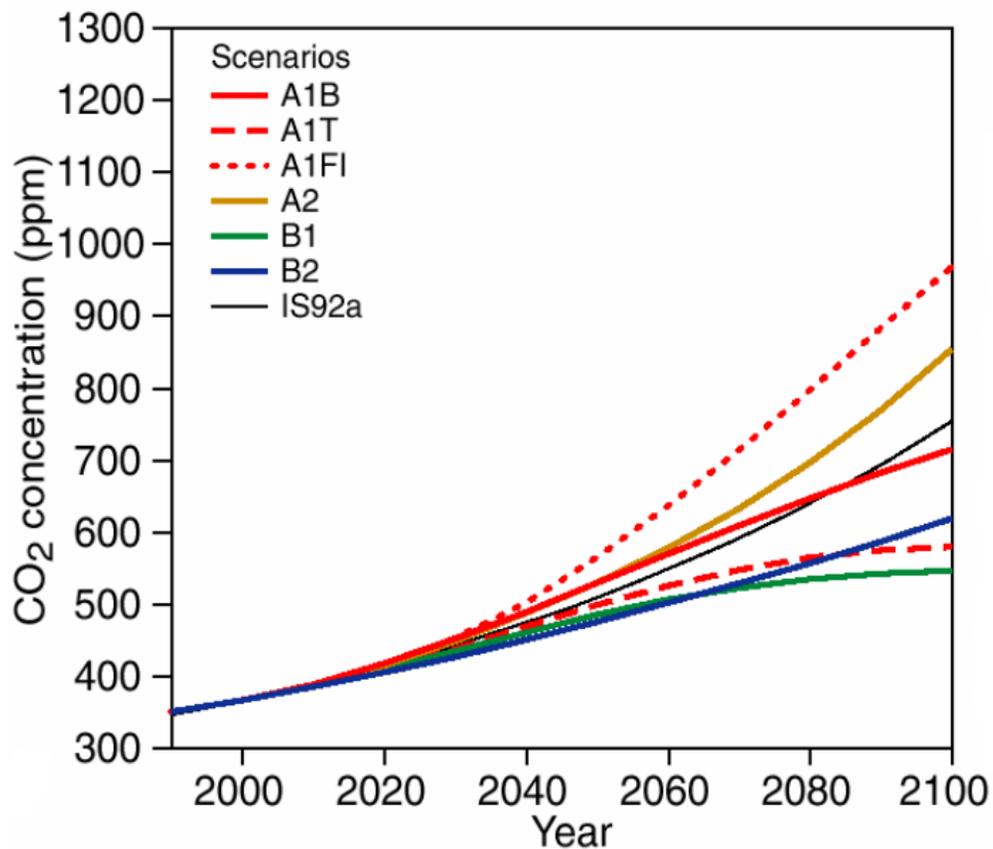
*It can be downloaded off the internet for free.*



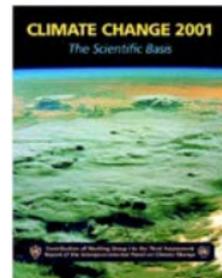
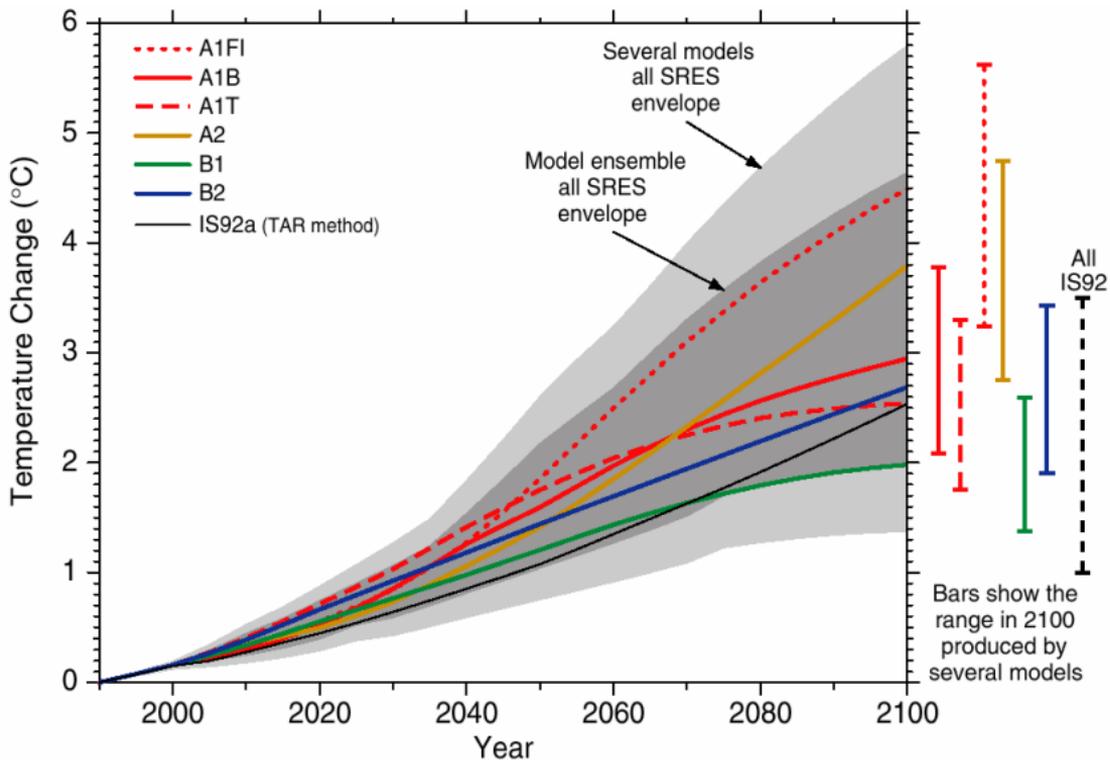
# PROJECTIONS OF FUTURE CO<sub>2</sub> EMISSIONS



# PROJECTIONS OF FUTURE CO<sub>2</sub> CONCENTRATIONS

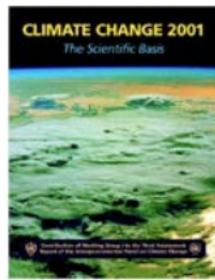
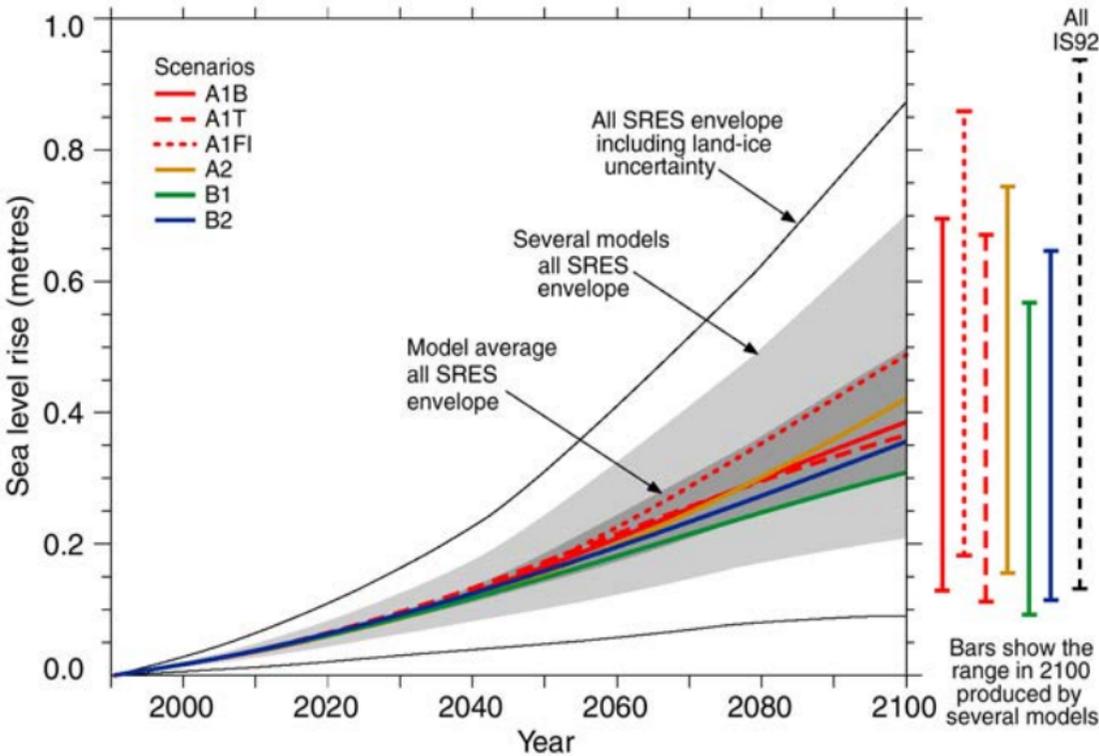


# PROJECTIONS OF FUTURE TEMPERATURE CHANGE



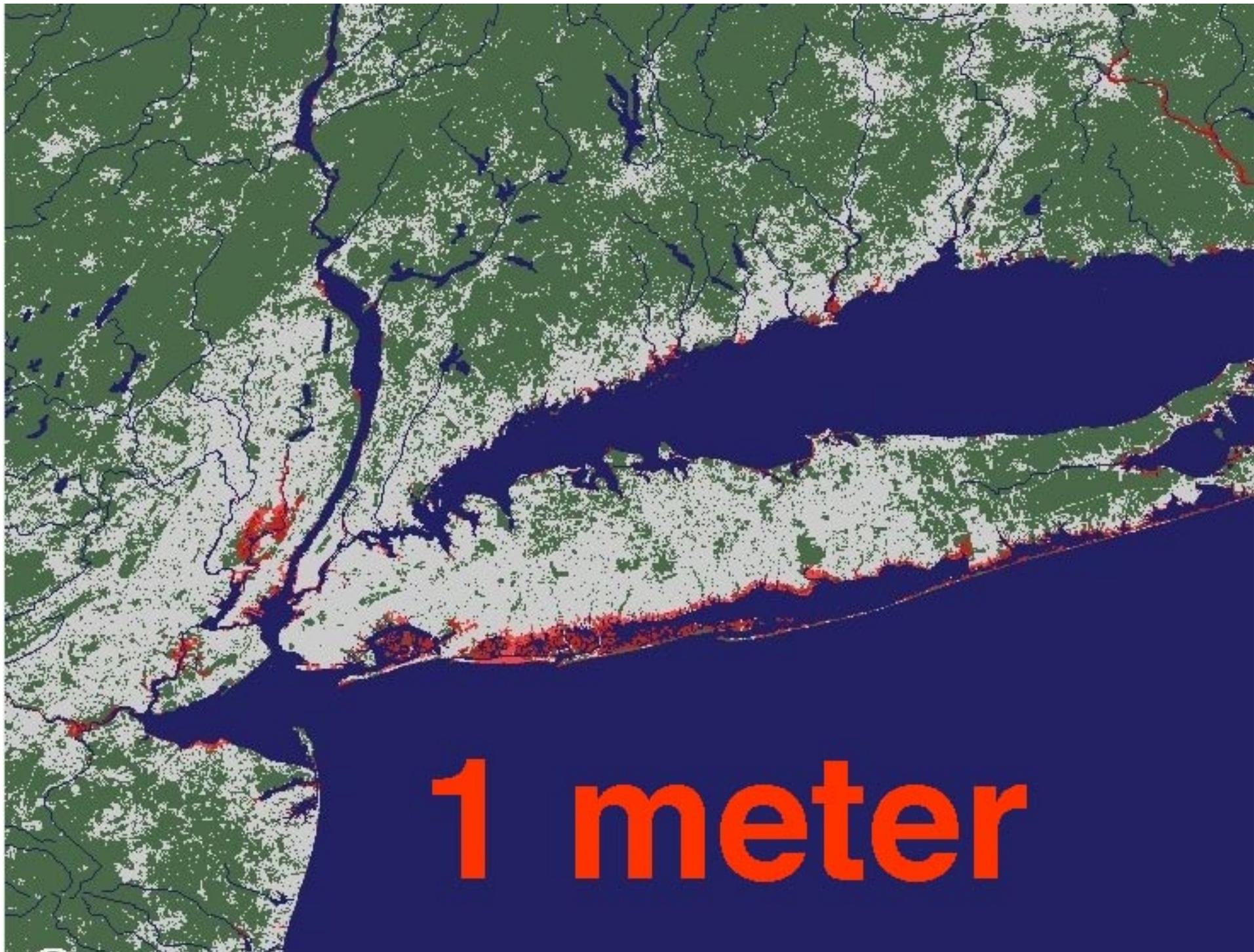
Bars show the range in 2100 produced by several models

# PROJECTIONS OF FUTURE SEA LEVEL RISE





**present**



***WHERE IS THIS CARBON DIOXIDE COMING FROM?  
WE ARE ALL RESPONSIBLE.***



Burning a gallon of gasoline in your car puts 5 pounds of carbon in the atmosphere as carbon dioxide (CO<sub>2</sub>), and it will stay there for decades — maybe a century!

Other sources are home heating and electric power production.



# Global Atmosphere, Global Warming

## QUESTIONS ABOUT GLOBAL WARMING

- IS IT REAL?
- IS IT IMPORTANT?
- WHAT IS IT DUE TO?
- HOW MUCH MORE CAN WE EXPECT?
- ARE WE SEEING JUST THE TIP OF THE ICEBERG?



***RESEARCH IS HELPING  
TO ANSWER THESE QUESTIONS.***

***[www.ecd.bnl.gov/steve](http://www.ecd.bnl.gov/steve)***