Exploring Earth's Energy Balance, Carbon Cycle, and Our Changing Atmosphere

National Science Teachers' Association Annual Conference,
Los Angeles, California
Thursday, March 30, 2017

Presented by Lori Lambertson, Exploratorium Teacher Institute

All today's activities and links are at:

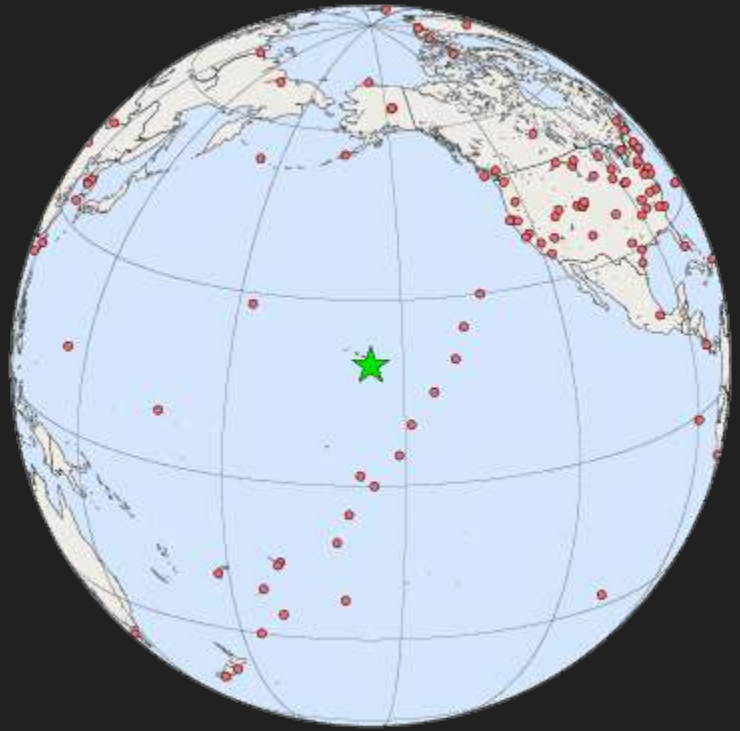
philo.exploratorium.edu/~loril/

Click on "Workshops", then "Exploring Earth's Energy Balance, Carbon Cycle, and Our Changing Atmosphere" at NSTA.

Our Changing Atmosphere

Graph NOAA data as an anchoring phenomenon to generate questions about our changing atmosphere.

Where is Mauna Loa?

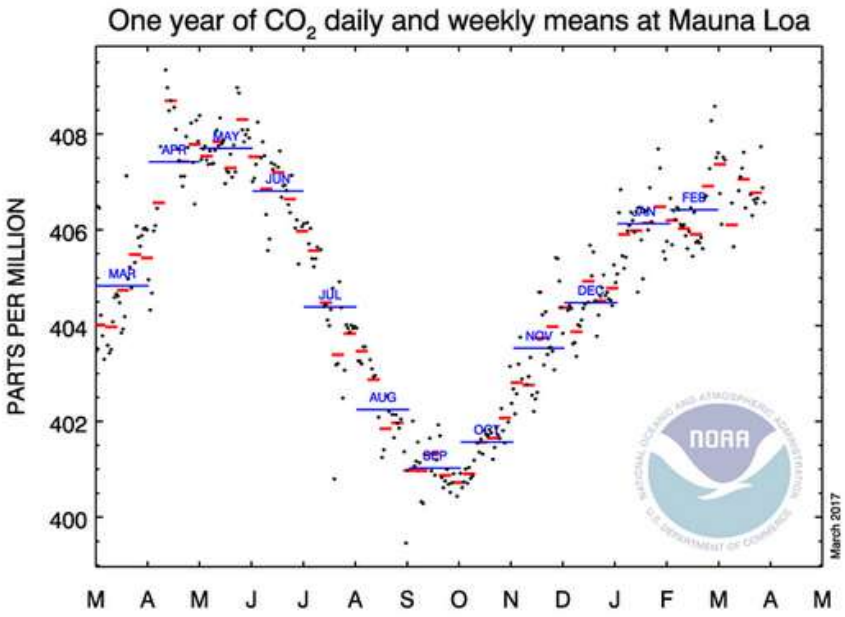


http://www.esrl.noaa.gov/gmd/dv/site/maps/MLO.png

What do you notice?

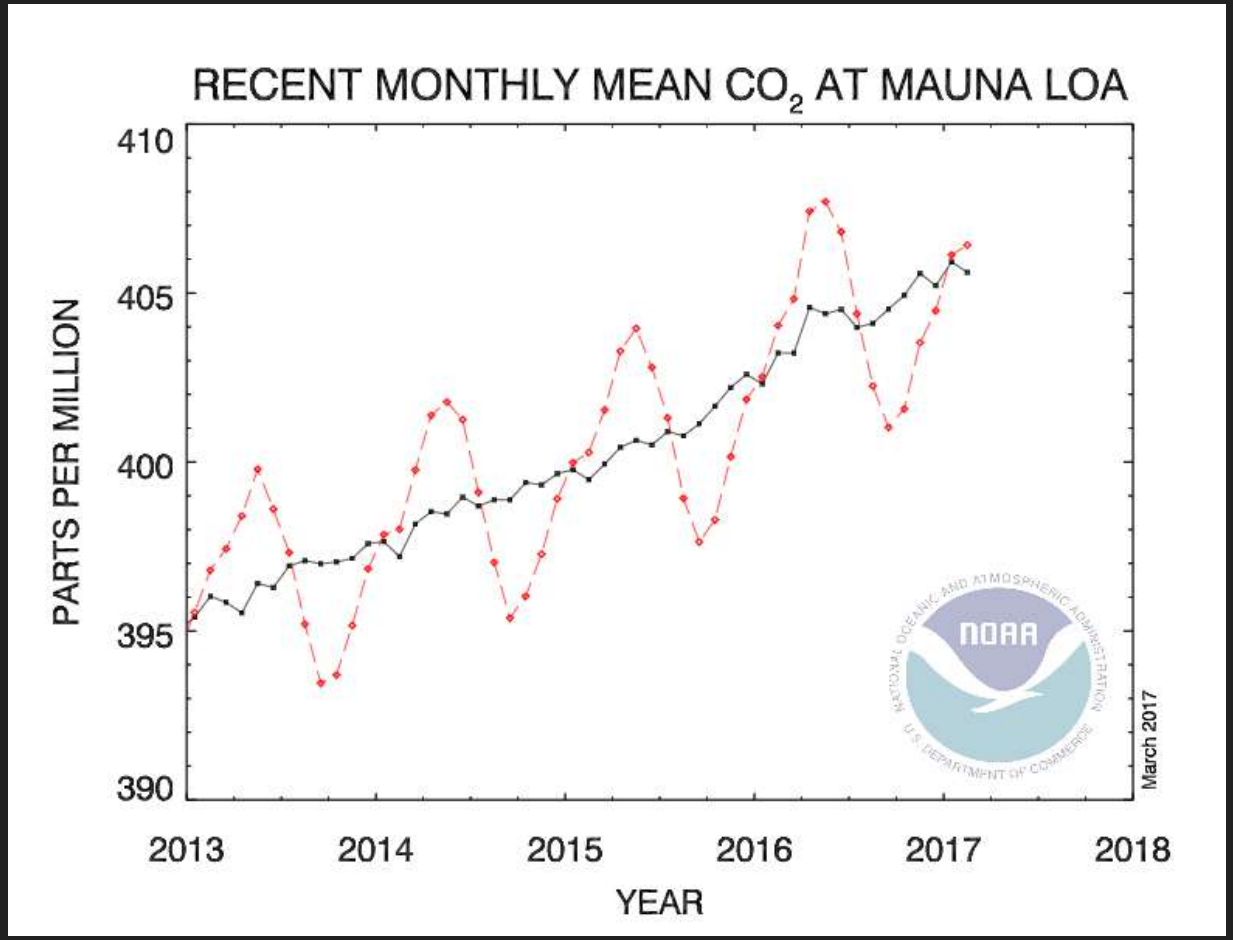
Up-to-date weekly average CO_2 at Mauna Loa

Week beginning on March 19, 2017: 406.77 ppm
Weekly value from 1 year ago: 405.37 ppm
Weekly value from 10 years ago: 385.28 ppm
Last updated: March 28, 2017

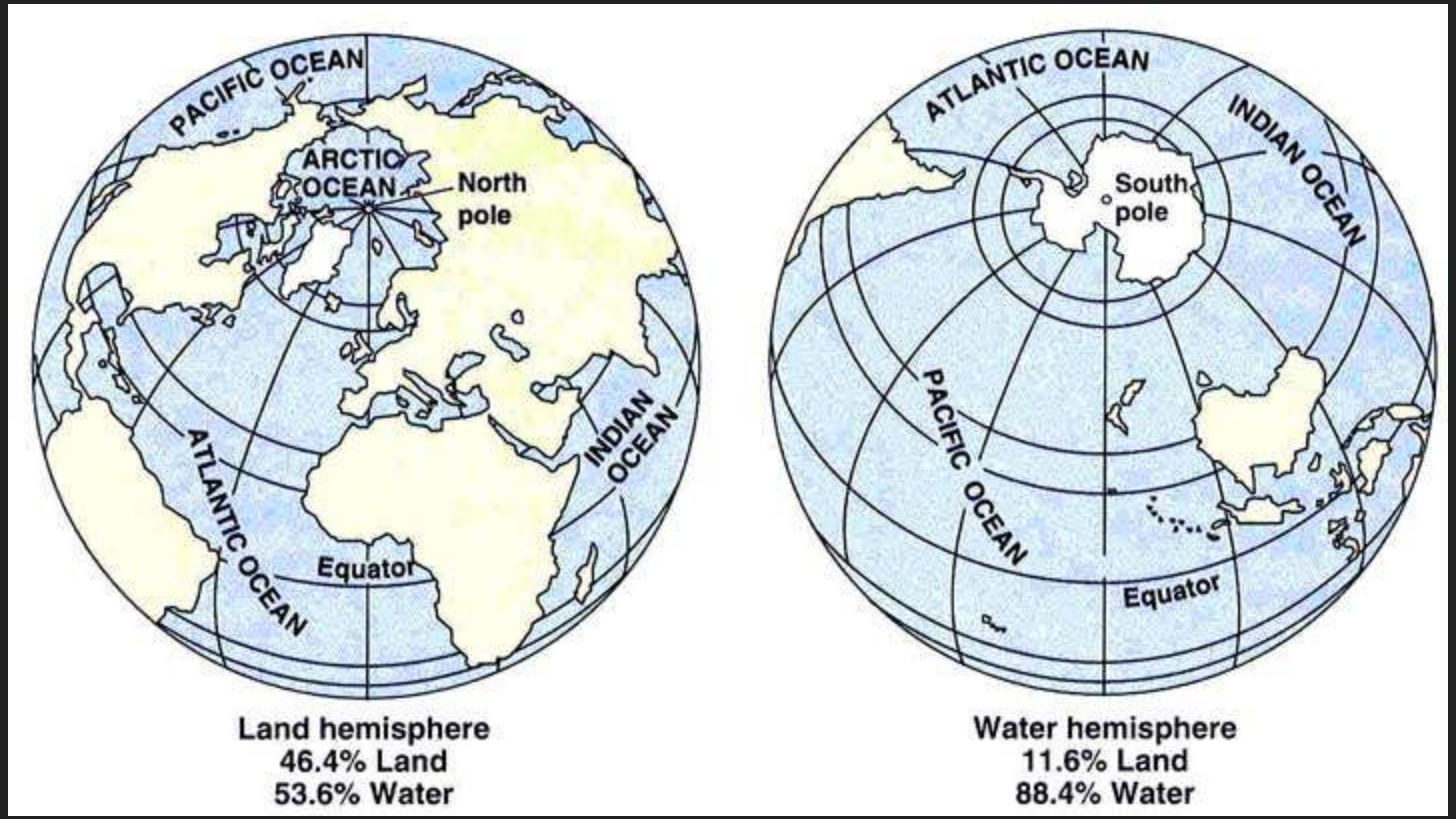


Preliminary weekly (red line), monthly (blue line) and daily (black points) averages at Mauna Loa for the last year.

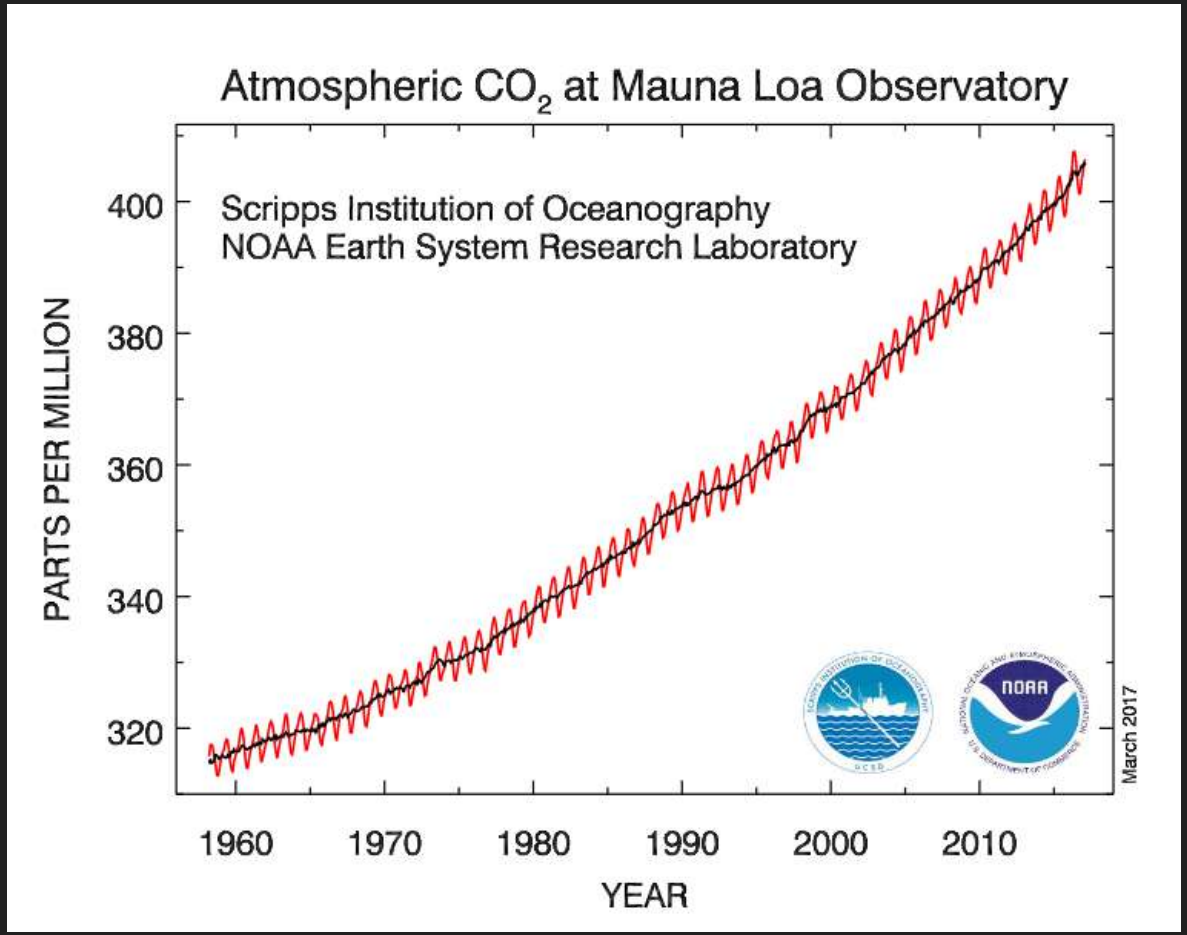
http://www.esrl.noaa.gov/gmd/ccgg/trends/weekly.html



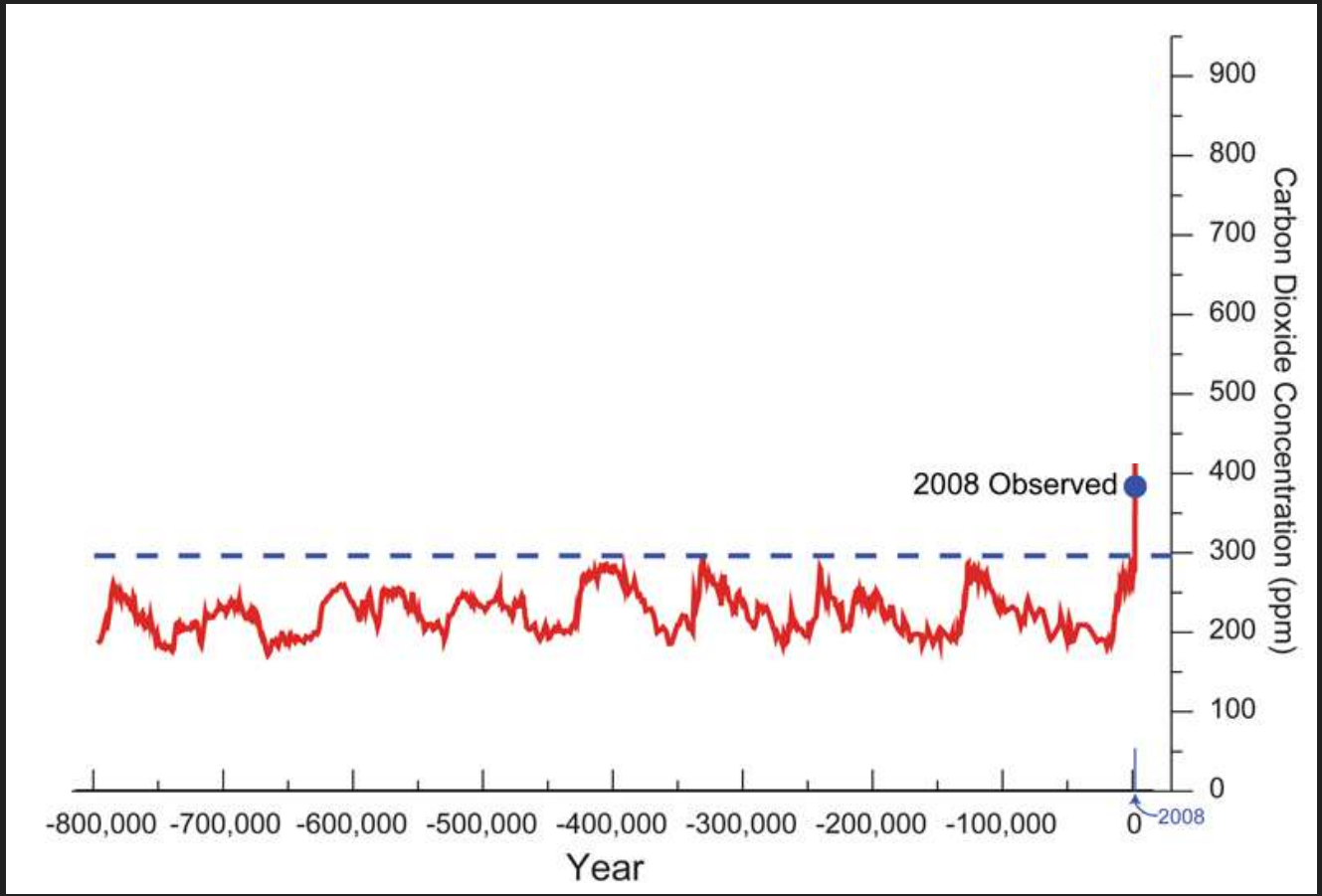
http://www.esrl.noaa.gov/gmd/webdata/ccgg/trends/co2_trend_mlo.pdf



http://paos.colorado.edu/~toohey/fig_51.jpg



http://www.esrl.noaa.gov/gmd/webdata/ccgg/trends/co2_data_mlo.png



http://www1.ncdc.noaa.gov/pub/data/cmb/images/indicators/800k-year-co2-concentration.gif

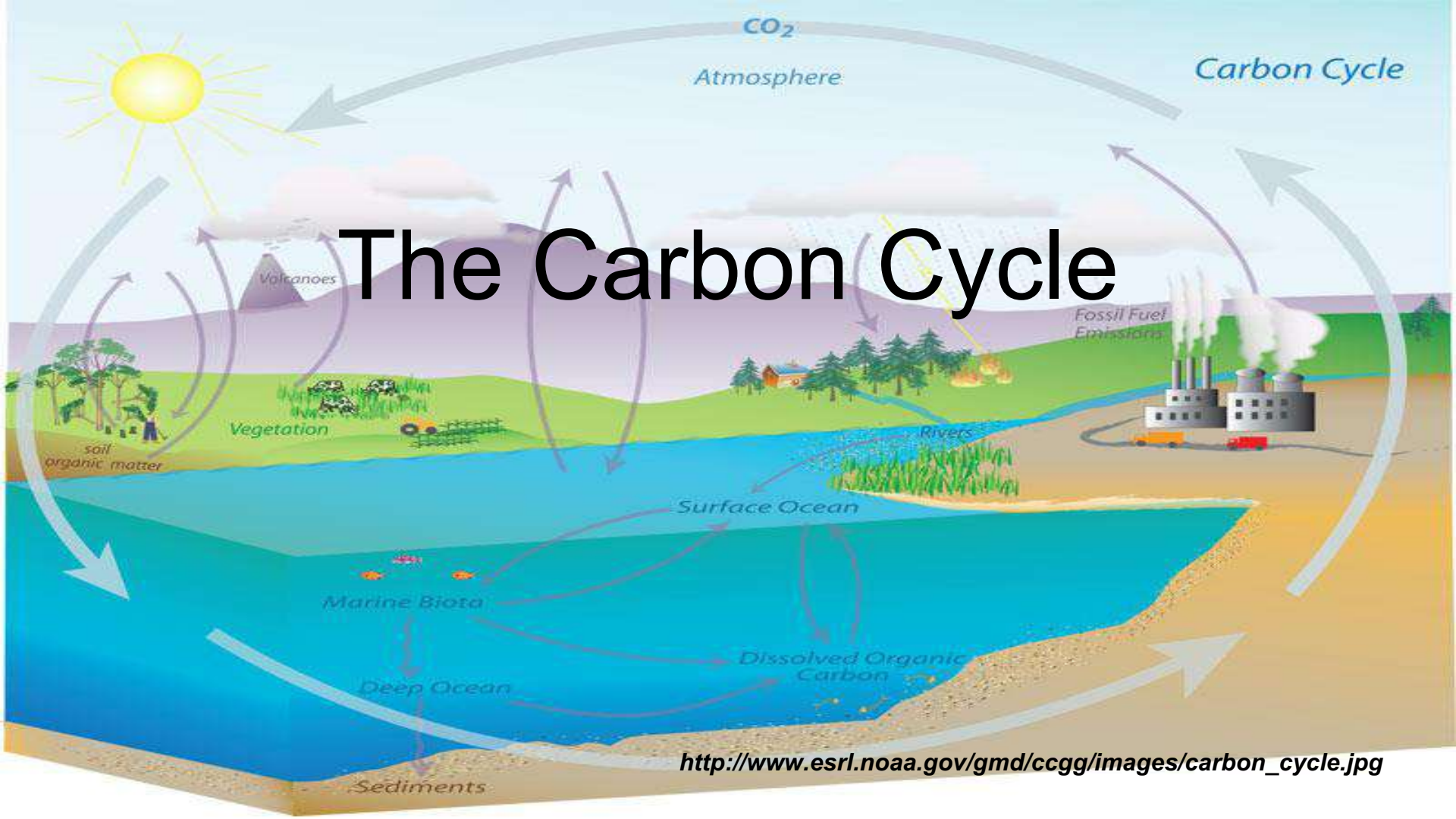
Follow the Carbon

Use rice to model the reservoirs and fluxes of carbon in the global carbon cycle, and help explain the graphs we made.

The Main Carbon Reservoirs

- Rock
- Ocean
- Terrestrial Biosphere
- Atmosphere
- Fossil Fuels

The Carbon Cycle



http://www.esrl.noaa.gov/gmd/ccgg/images/carbon_cycle.jpg

The Relative Abundance of Carbon in the Main Carbon Reservoirs

- Rock - 65,500,000 Gt C
- Ocean - 44,000 Gt C
- Terrestrial Biosphere - 2850 Gt C
- Atmosphere - 800 Gt C
- Fossil Fuels - 10,000 Gt C

GtC and PgC

GtC = Giga tons Carbon

Giga (10^9) x 1000 kg Carbon

10^9 x 1000 kg x 1000 g/kg Carbon

10^9 x 10^3 x 10^3 g = 10^{15} g Carbon

PgC = Peta grams Carbon

10^{15} g Carbon

Imagine San Francisco (10 km x 10 km)….

…buried in charcoal to a depth of 15 meters (4 stories)!

http://extras.sfgate.com/img/pages/travel/maps/sf-city_full.gif

Carbon Forms in Rock

Mostly solid carbonate, such as limestone, calcium carbonate ($CaCO_3$).

Carbon Forms in Surface Ocean

Various Dissolved Inorganic Carbon (DIC) species, including:

- Dissolved carbon dioxide (CO_2)
- Carbonic acid (H_2CO_3)
- Bicarbonate ion (HCO_3^{-1})
- Carbonate ion (CO_3^{-2}).

Carbon Forms in Terrestrial Biosphere

Organic plant material and soils

In the forms of simple sugars, like glucose or fructose

And more complex molecules like starch and cellulose.

Carbon Forms in Atmosphere

The most abundant form is carbon dioxide (CO_2)

Also

Methane (CH_4)

Carbon monoxide (CO)

Carbon Forms in Fossil Fuels

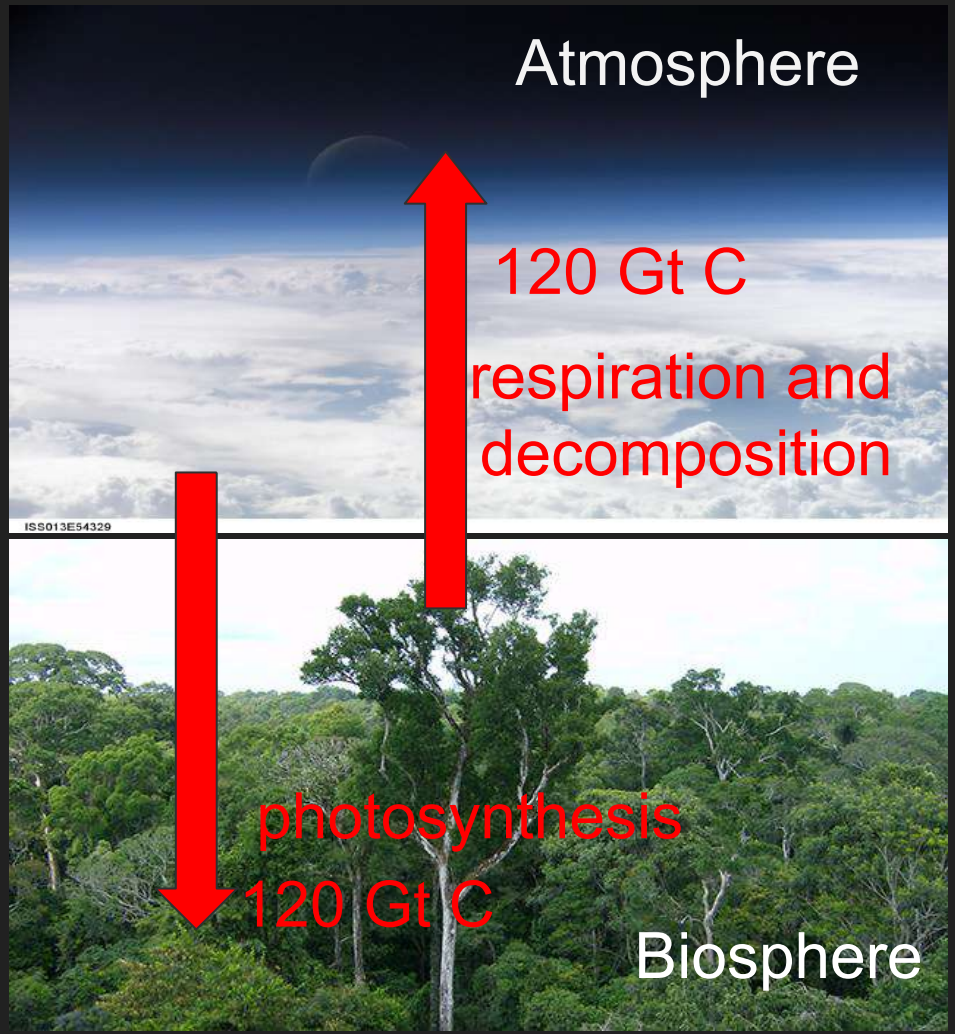
Solid coal

Liquid hydrocarbon petroleum

Gas hydrocarbon methane

The Fast Carbon Cycle

120 Gt C/year is exchanged between the atmosphere and the terrestrial biosphere.

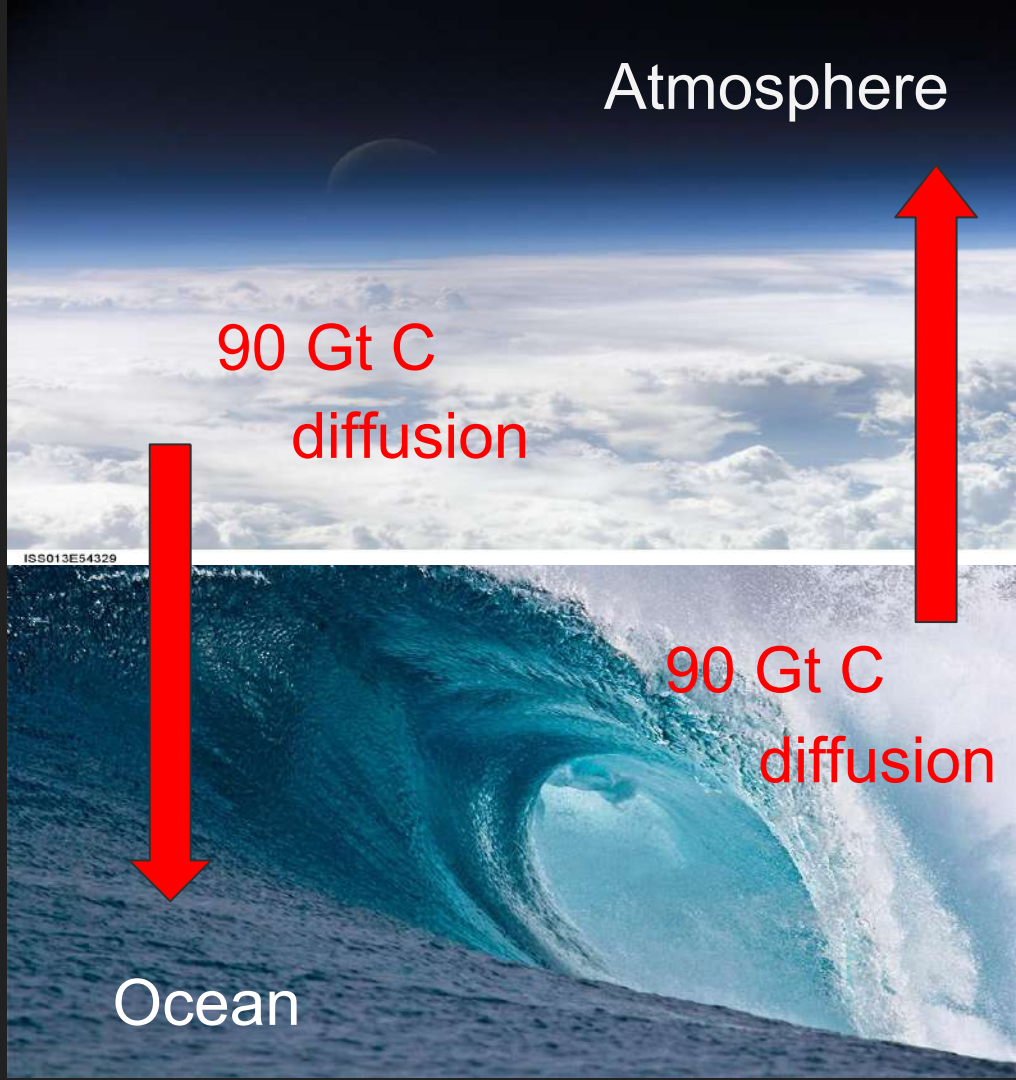


http://www.jpl.nasa.gov/news/news.php?release=2014-0

http://eoimages.gsfc.nasa.gov/images/imagerecords/7000/7373/ISS013-E-54329_lrg.jpg

The Fast Carbon Cycle

90 Gt C/year is exchanged between the atmosphere and the oceans.



http://www.nesdis.noaa.gov/news_archives/wod_2013.html

http://eoimages.gsfc.nasa.gov/images/imagerecords/7000/7373/ISS013-E-54329_lrg.jpg

What do you notice?

The S - l - o - w Carbon Cycle

Carbon takes 100s of millions of years to cycle between rocks, soil, ocean and atmosphere.

http://3dparks.wr.usgs.gov/grca/phantom_ranch/html/grand009.htm

Fossil Fuels

- Part of the Slow Carbon Cycle
- Were formed 100s of millions of years ago
- Terrestrial plants formed coal
- Marine organisms (plankton) formed oil

http://www.esrl.noaa.gov/gmd/ccgg/basics.html

Fast Carbon Cycle:

Time Scale:
Months to years to decades

Flux amounts:
~200 Gt C/year

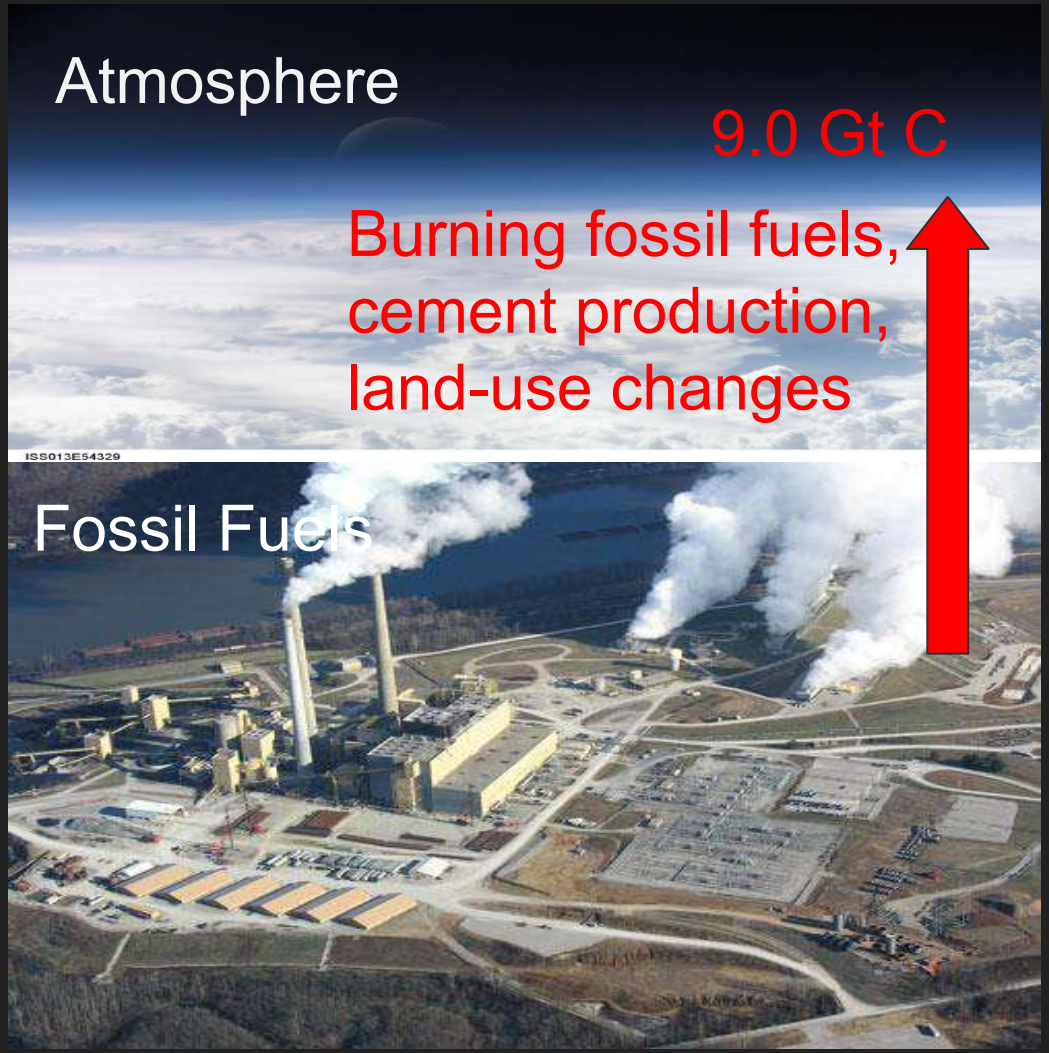
Slow Carbon Cycle:

Time Scale:
100s of thousands to 100s of millions of years

Flux amounts:
0.01 - 0.1 Gt C/year

Human activities and the Carbon Cycle

Human activities are currently contributing 9 Gt C to the atmosphere every year.



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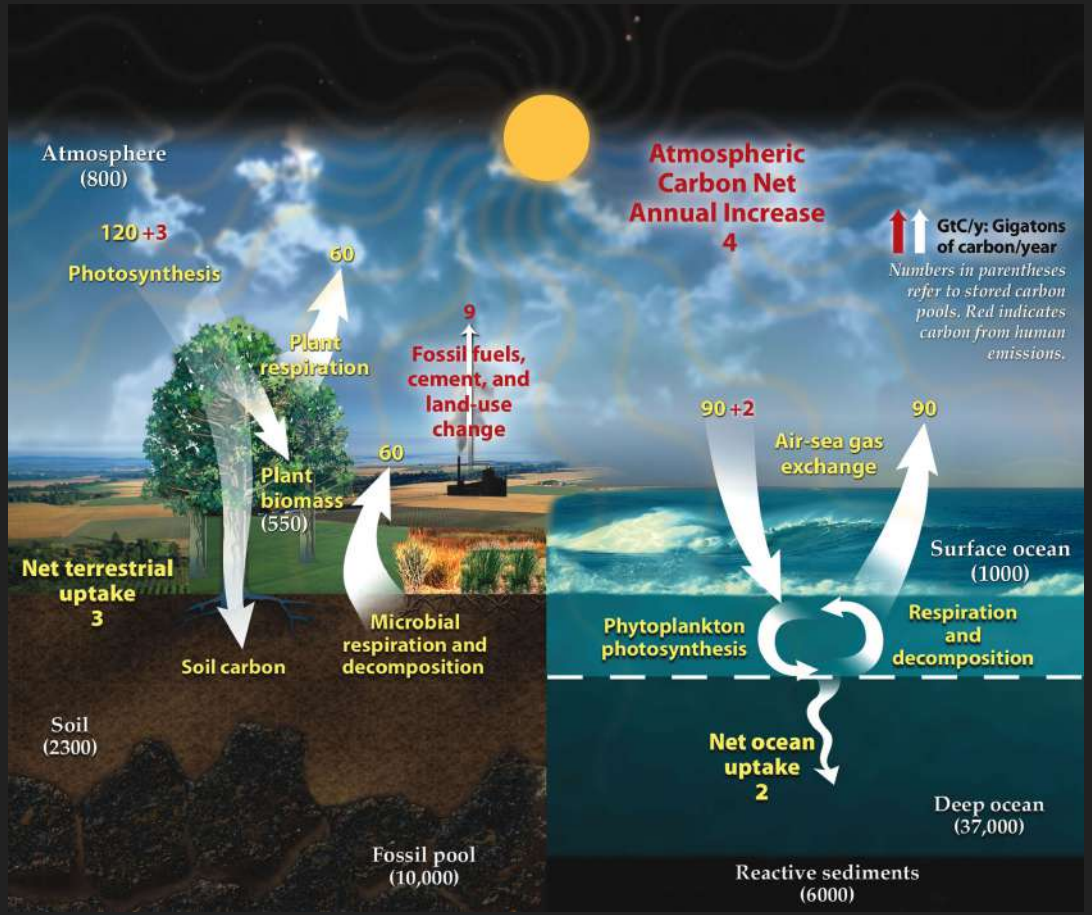


https://public.ornl.gov/site/gallery/originals/BioComponents_Carbon.jpg

Earth’s Energy Budget

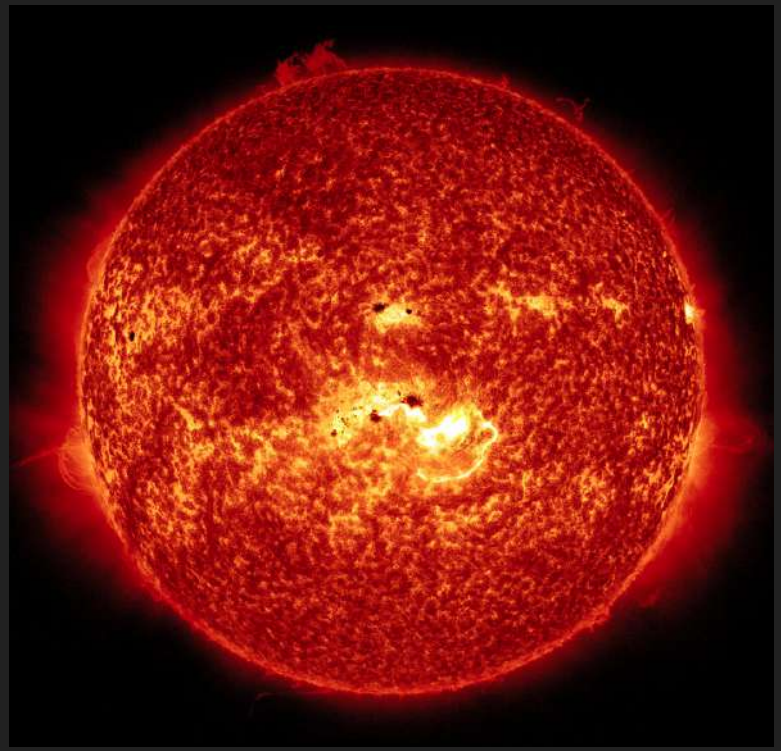
Use beans to model energy flows in the earth system.

Modeling Earth's Energy Budget

The beans represent energy.

Your cup can be the SUN, the source of almost all energy on our planet.

Label one area "EARTH", one area "SPACE", and another area "ATMOSPHERE".



https://www.nasa.gov/sites/default/files/jan_7_x_flare_1600-304.jpeg

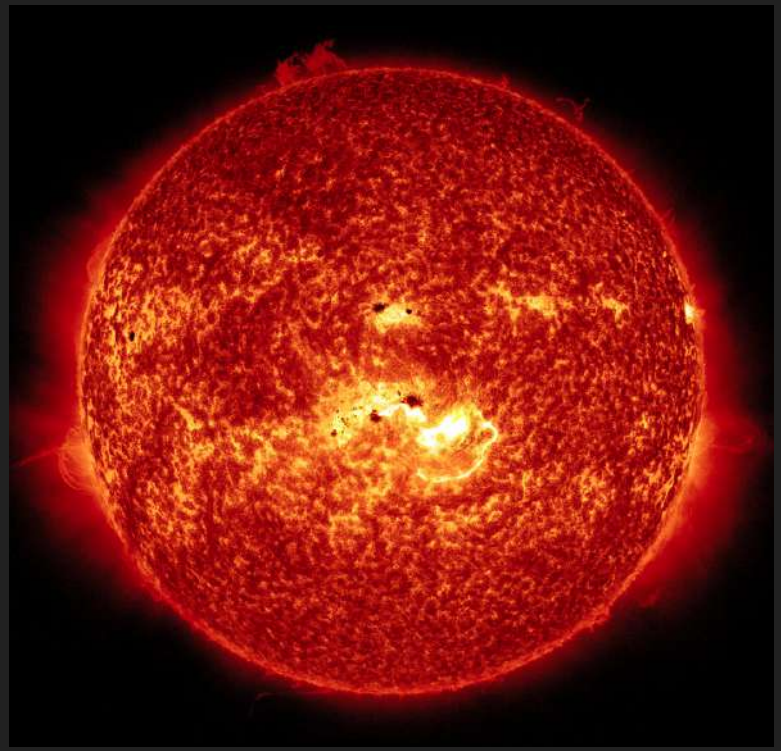
SCENARIO ONE

The sun gives the earth 10 beans.

The earth keeps half and returns half to space.

Count the beans the earth has and record.

Repeat.



https://www.nasa.gov/sites/default/files/jan_7_x_flare_1600-304.jpeg

What do you notice?

SCENARIO TWO

The sun gives the earth 10 beans.

The earth sends half its total beans to the atmosphere.

The atmosphere takes that total and divides it, sending half back to earth, and half to space.

Count the total number of beans the earth has and record.

Repeat.

SCENARIO THREE

Start with 30 beans on earth.

The sun gives the earth 10 beans.

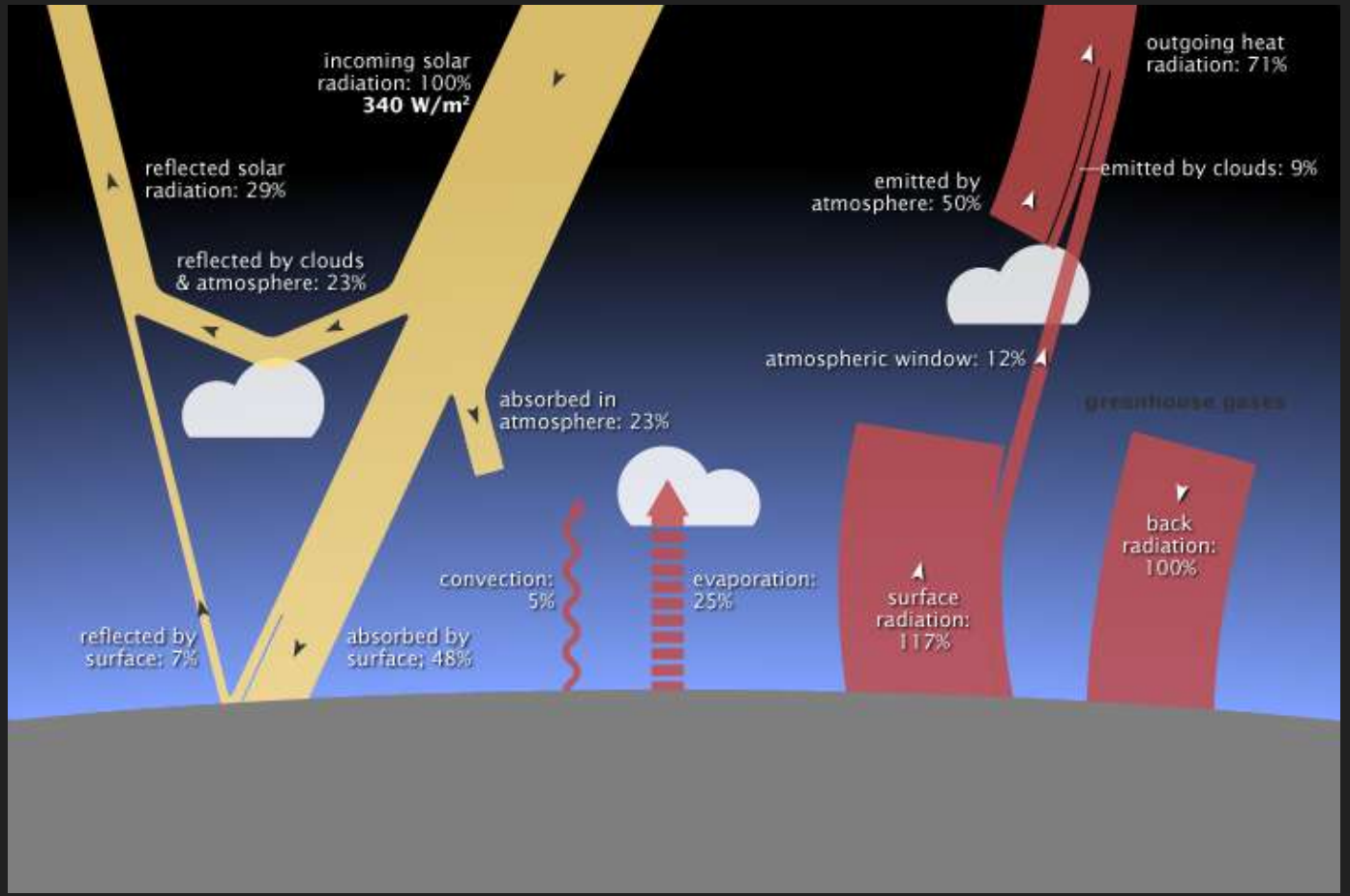
The earth sends half its total beans to the atmosphere.

The atmosphere takes that total and sends 2/3 back to earth, and ⅓ to space.

Count the total number of beans the earth has and record.

Repeat.

What do you notice?



https://earthobservatory.nasa.gov/Features/EnergyBalance/images/global_energy_budget_components.png

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For more activities from the Exploratorium, visit our Science Snack page:
www.explorartorium.edu/snacks

Thank you!

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