

# CLIMATE CHANGE CRITICALITY

The narrative posted here combines the discussion portions of Stations 18, 19 and 20 of *Exploring Matter: An Interactive, Inexpensive Chemistry Exhibit for Museums* (see: <http://murov.info/EM-TOC.htm>), an exhibit just opened up for visitors (09/13/16) in Modesto Junior College's Great Valley Museum. Intended to supplement climate change sites posted earlier (see: <http://murov.info/climatechange.htm> and <http://murov.info/climatechangeimages.ppt>), this posting was prompted by the urgent need for a global response to the threat of climate change. While many people either do not consider climate change a real concern or a problem that will not surface for decades, significant evidence is accumulating that the earth is already experiencing detrimental effects that will only get much more severe if corrective action is not taken. Doctors report that rising temperatures have increased the length of the allergy season and more are suffering and even dying from abnormally long periods of high temperatures. Droughts, wildfires and floods are becoming much more common. While sea levels are only in the early stages of expected rises, with even the small changes that have occurred, high tides and storms are causing much more coastal damage. There is a tendency for societies to take appropriate action only in the time of a crisis. Unfortunately, action to minimize the effects of fossil fuel combustion will take decades to implement and even more time to be effective. Everyday that we wait exacerbates the problem and our grandchildren will pay a huge penalty. Waiting for the climate change crisis is an unacceptable pathway and the route to disaster.

## Complacency = Disaster

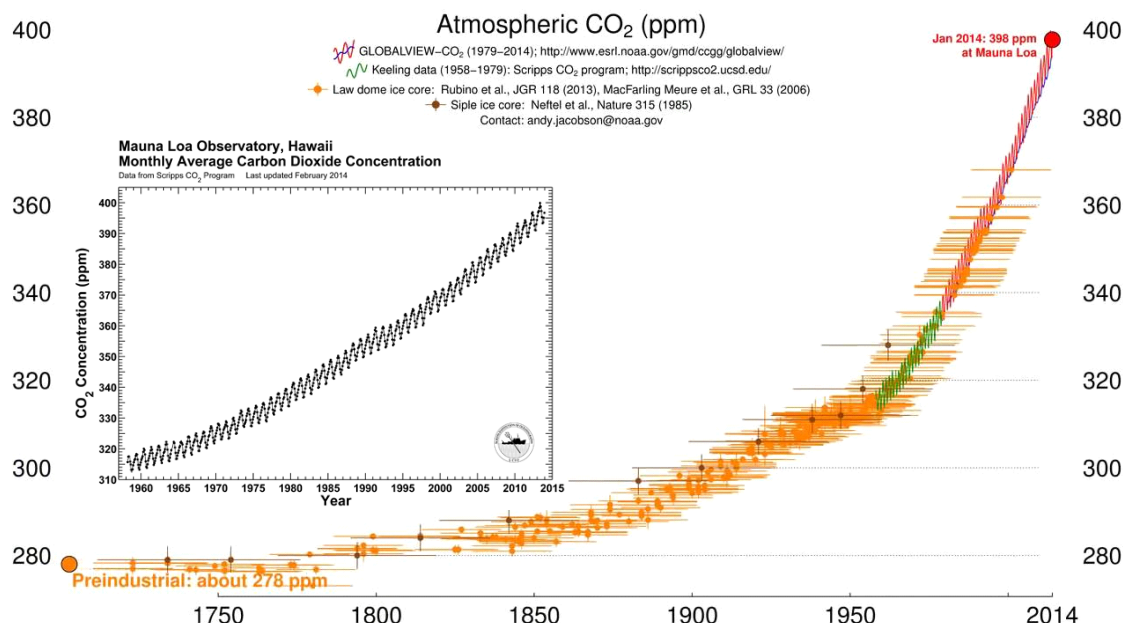


**Unacceptable behavior that will lead to a much lower quality of life. Corrective action is needed now.**

***We do not inherit the Earth from our Ancestors,  
we borrow it from our Children.***  
**Native American Proverb**

# STATION 19 - FOSSIL FUEL ISSUES AND CLIMATE CHANGE

Conviction in a jury trial requires evidence beyond a reasonable doubt. The evidence that human use of fossil fuels causes substantial amounts of human and animal suffering and extensive environmental degradation goes far beyond a reasonable doubt. Significant climate change is just one of the negative consequences of fossil fuel combustion that along with other issues poses a severe threat to our quality of life. What is the compelling evidence?

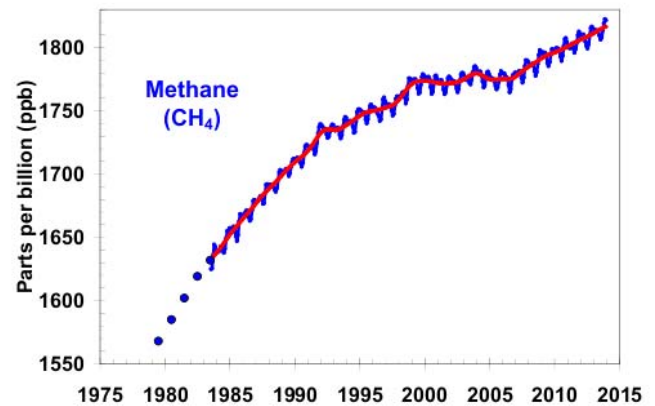


**CARBON DIOXIDE.** The graphs above clearly and definitively show that the carbon dioxide (CO<sub>2</sub>) content of our atmosphere has increased from a value of 278 ppm (or 0.0278 %) in preindustrial time to about 398 ppm (or 0.0398% and rising) in 2014 or a 43% increase in CO<sub>2</sub> concentration in the atmosphere. How is it possible that human activity has been able to change the content of such a huge part of the earth's environment? Although most people have an opinion about climate change, most have little understanding of the science and the potential impacts of atmospheric changes. To illustrate this point, the atmosphere plays a major role in the science of climate change but most people cannot name both of the two most abundant gases in our atmosphere. Can you name them without peeking below?

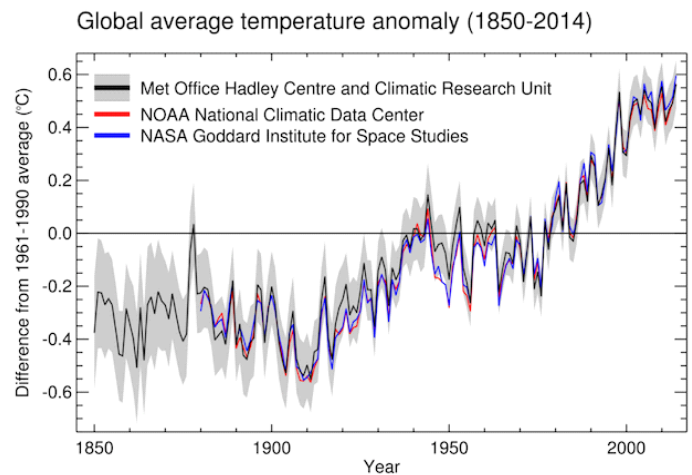
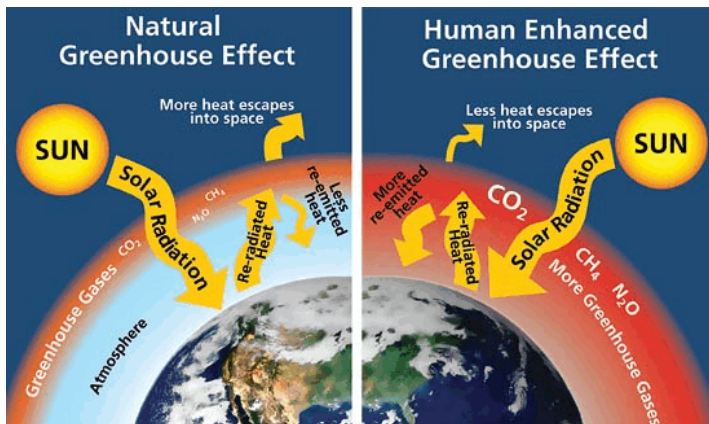
Gas	formula	% <sup>1</sup>	ppm
nitrogen	N <sub>2</sub>	78.082	780,820
oxygen	O <sub>2</sub>	20.946	209,946
argon	Ar	0.934	9,340
carbon dioxide	CO <sub>2</sub>	0.040	400
neon	Ne	0.0018	18
helium	He	0.0005	5
methane	CH <sub>4</sub>	0.0002	2
krypton	Kr	0.0001	1
hydrogen	H <sub>2</sub>	0.00005	

<sup>1</sup> Water varies from about 0.5% to 4% and is often the third most abundant gas in the atmosphere.

Extremely few can name the top three. Most important to note is that  $\text{CO}_2$  ranks only 4<sup>th</sup> and has the very low current value of 0.04%. As a result of the low amount, human burning of fossil fuels produces amounts of  $\text{CO}_2$  comparable to the total amount in the atmosphere and has caused the increase in  $\text{CO}_2$  concentration in the atmosphere. In addition to  $\text{CO}_2$ , other gases such as methane ( $\text{CH}_4$ ) are also increasing in atmospheric concentration.



**GLOBAL WARMING.** What are the environmental changes that result from changes in atmospheric composition? Both  $\text{CO}_2$  and  $\text{CH}_4$  absorb infrared radiation emitted from the earth. For some of the science supporting this, please refer to a later section. Increases in the concentrations of these gases results in the trapping of more energy and higher temperatures on the surface of the earth.

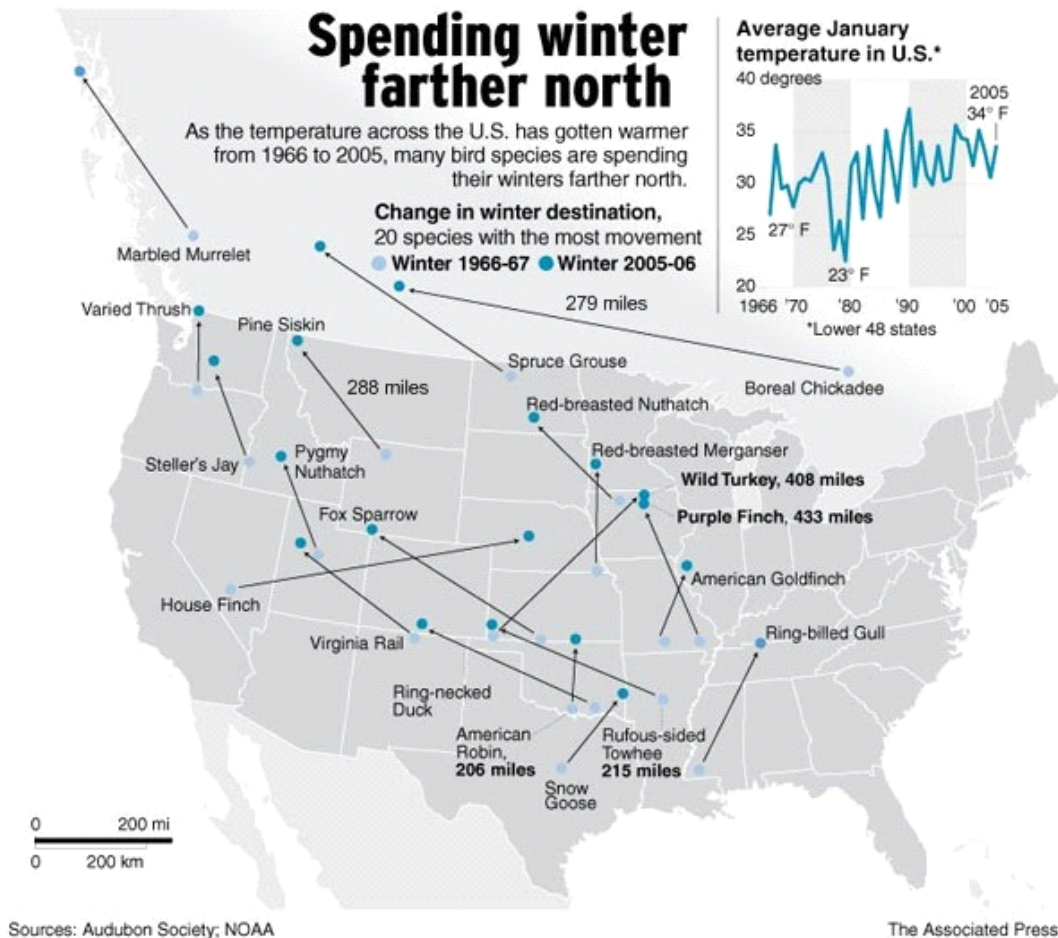


Do measurements of global temperatures provide evidence that the increase in  $\text{CO}_2$ ,  $\text{CH}_4$  and other Greenhouse gases is causing the global temperature to increase? The graph to the above right and the charts in **Station 20** demonstrate that global warming is occurring. The observed increase in temperature cannot be explained using natural astronomical variations but is completely consistent with scientific modeling that takes into account human contributions to atmospheric changes. Observed sea level increases, ice mass loss and changes of animal habitats add further evidence that Greenhouse gases are dangerously impacting our environment.

**What are the consequences of global warming?** Warmer temperatures are already severely affecting the health of hundreds of thousands if not millions of people. Deaths from heat waves are on the rise. The allergy season has been extended an estimated 3 weeks/yr. Agriculture is affected and rain patterns are changing with very damaging drought a common problem. Wild animals are being forced to change their habitat locations. Wildfires and freaky weather have become much more common and both are wreaking havoc and mayhem around the globe.



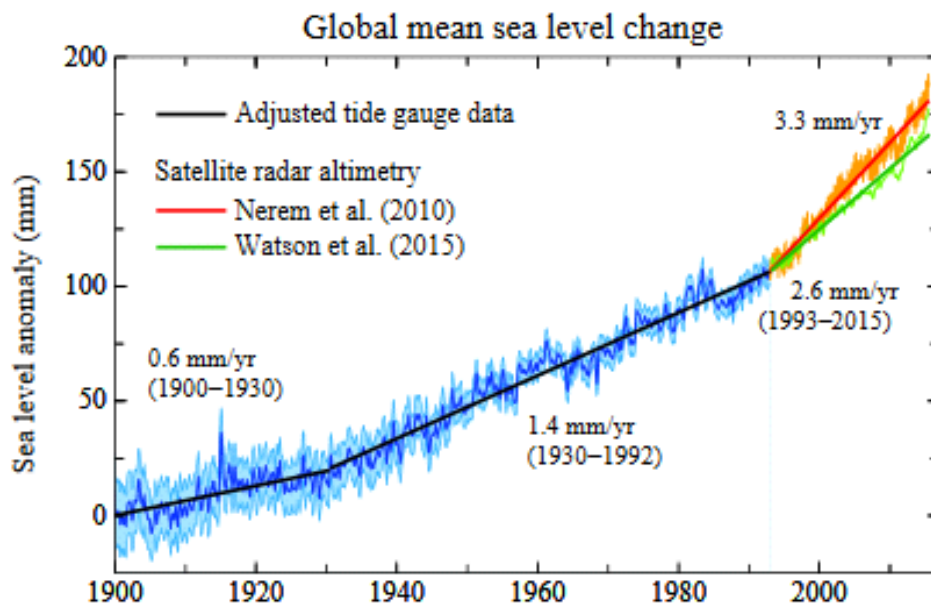
## HABITAT CHANGE.

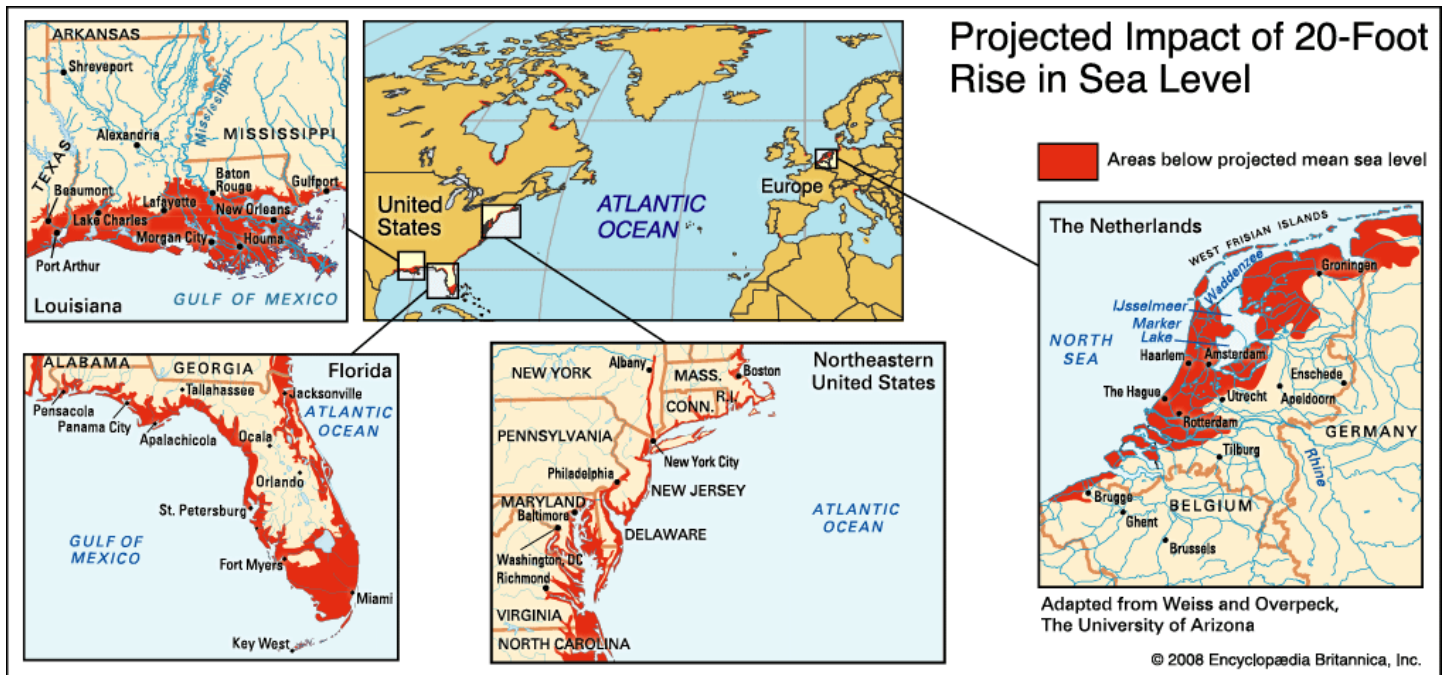


**SEA LEVEL RISE.** Increasing atmospheric temperatures cause the temperature of the oceans to rise and the glaciers and ice masses of the earth to melt. An increase in ocean temperature causes a decrease in the density of water and an expansion of volume. Ice melting also causes an increase of ocean volume. Combined, the increase of volume is a severe threat to all coastal communities. (For sea level rise maps, see:

<http://geology.com/sea-level-rise/> )

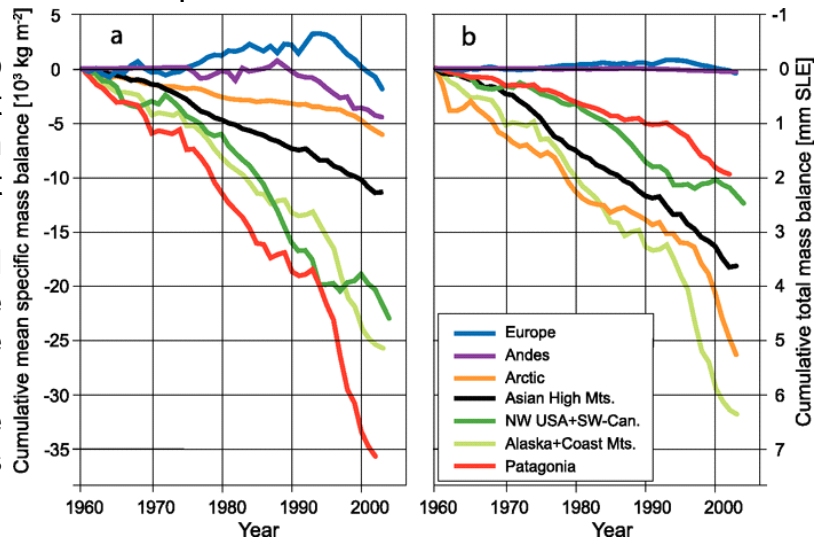
[om/sea-level-rise](http://geology.com/sea-level-rise/)



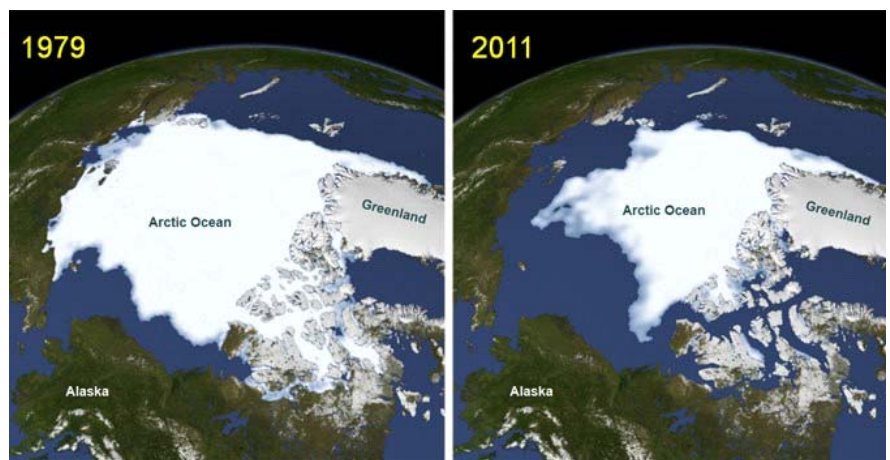


The maps above show the devastating effects of 20 feet of sea level rise in a few locations on the earth. The demonstration that accompanies this station (19) shows the dramatic effects of 100 feet of sea level rise on the S.F. Bay area and Florida. While 100 feet is probably close to a worst case scenario, 20 feet is within scientific predictions.

**ICE MASS LOSS.** The graphs to the right and the image to the lower right show that the ice masses of the earth are undergoing a rapid melting that poses many more threats to life on earth. In addition to raising the sea level and threatening coastal communities, the ice mass loss threatens to eliminate the habitats of polar bears and walruses. Many populations of people will lose their source of fresh water if the glaciers disappear.

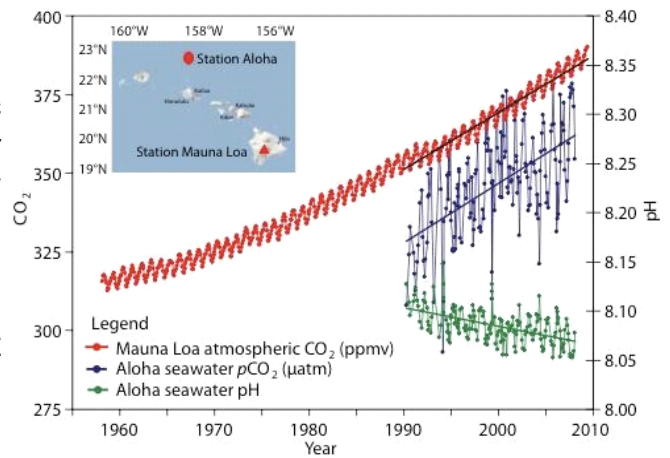


The discussion has only mentioned a few of the problems caused by human use of fossil fuels. Every year, many people die in mining, pipeline and oil rig accidents. Air and water pollution are two more terrible results of the use of fossil fuels. Wars have been attributed to fossil fuel issues. Acidification of oceans is another threat.



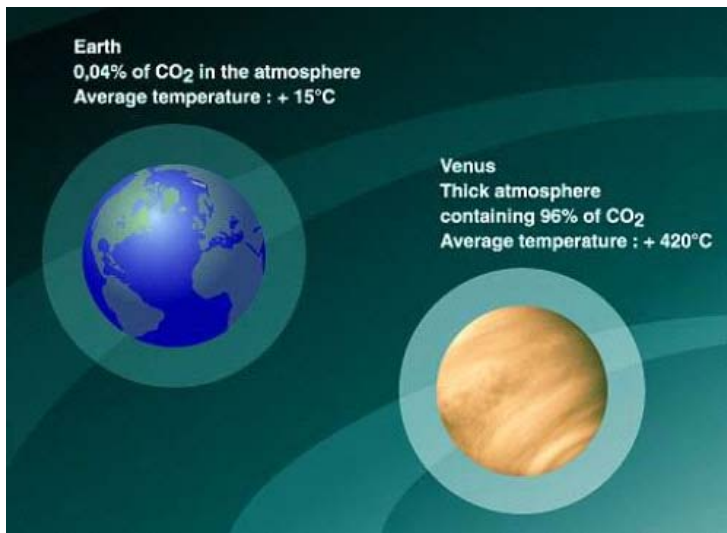


**OCEAN ACIDIFICATION.** The atmospheric  $\text{CO}_2$  increase would be much bigger were it not for  $\text{CO}_2$  absorption into the ocean.  $\text{CO}_2$  is absorbed by the oceans and converted into carbonic acid. This results in an increase in the acidity of the ocean and a decrease in the pH. Already, the pH has dropped from about 8.2 to 8.07. A pH decrease is a direct threat to all shell fish and coral reefs. Observations indicate that the Australia's Great Barrier Reef is disappearing and will be gone in a few decades.



The use of fossil fuels has rapidly changed the world and in many ways has improved the quality of life. On the other hand, **continued use of fossil fuels severely threatens the quality of life for our grandchildren.** Considering all the evidence, a jury would have to find humans guilty of endangering the future of life on earth. If we continue down our present path, countless unnecessary deaths will result and more animals will become extinct. We are already experiencing many disturbing consequences of fossil fuel use. There is still time to minimize the negative effects and avoid an economic downturn and eventual calamity. However, action is needed now as the remedies take decades to implement. Every day lost without action increases the long term severity of the negative impacts of fossil fuels.

Do we want the earth to resemble Venus, a planet with a runaway Greenhouse effect?



**SOLUTIONS.** Steps must be taken to phase out the use of fossil fuels rapidly.

1. One step towards achieving this goal is to initiate a carbon neutral fee and dividend on the use of carbon based energy sources.
2. Strongly encourage conservation.
3. Strongly encourage development and use of more solar, wind and tidal energy sources. Require that new construction include solar panels for at least 80% of their energy use.
4. Strongly encourage the use of electric and hybrid vehicles.
5. Invest significantly in energy research to improve solar panel efficiency and to develop new energy sources such as nuclear fusion and artificial photosynthesis.

## Addendum.

The following image from Crystal Cruise Lines demonstrates that climate change has already had a significant impact on the environment of the earth. Explorers started searching for a Northwest passage about 500 years ago. However, a safe navigation route was not possible until a couple of years ago. Global warming has caused enough of a decrease in Arctic ice mass that the Northwest passage is now open for part of the year. Immediately threatened are the polar bears and walrus but all life on earth is now under threat from the impact of fossil fuel consumption. Please notice in the map on the right the significant shrinkage of the Arctic ice mass.

### Luxury cruise conquers fabled route

The first large-scale passenger cruise ship is to sail through the Northwest Passage, the Arctic sea route made navigable by steadily shrinking ice cover. The route has never before been attempted by a ship of this size

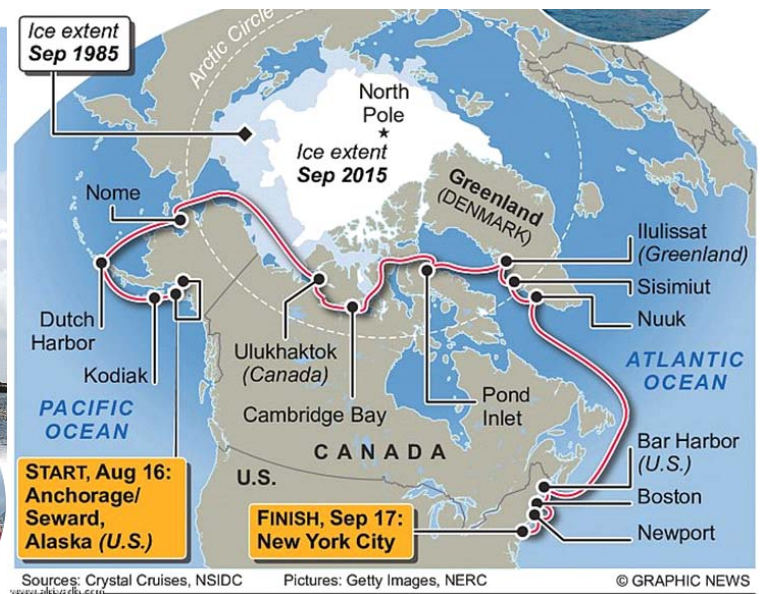
#### CRYSTAL SERENITY

Length **250m** Crew **655**  
Beam **32m** Passengers **1,000**  
Draught **8m** Ticket **\$22,000**  
Decks **13**

**SAFETY MEASURES:** Ship fitted with ice detection radar, special search lights, thermal imaging and navigation system that displays near real time satellite ice imagery



**RRS Ernest Shackleton:** British research vessel will escort Serenity to provide ice-breaking assistance. Ship carries two helicopters for real-time ice reconnaissance, emergency support and sightseeing flights



### Anchorage to New York City

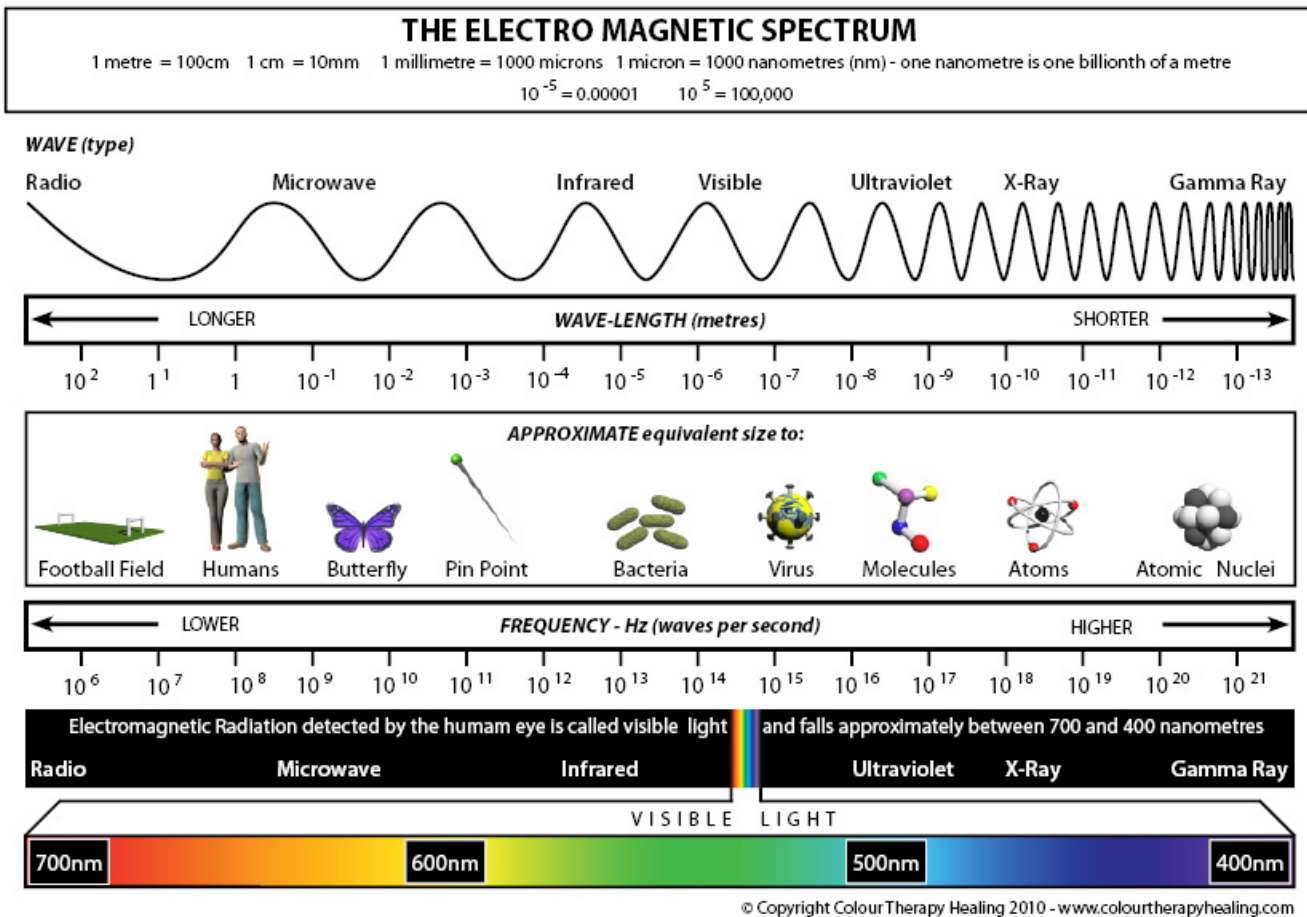
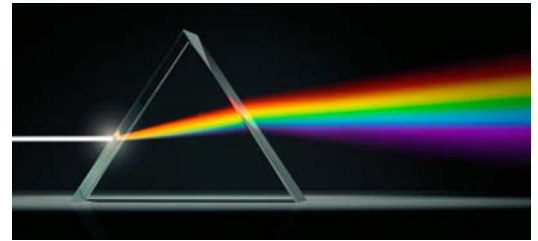
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## Spectroscopy: A Powerful Tool for Scientists

Scientists take advantage of a huge range of the electromagnetic radiation spectrum (often referred to as light even though only a small portion is detectable by the human eye) to probe matter. Gamma rays, x-rays, ultraviolet, visible, infrared, microwave and radio wavelengths enable detection and determinations of concentrations, structures and properties. Health related fields rely on spectroscopy to analyze a myriad of tests. MRI (magnetic resonance imaging) is invaluable for determining the cause of health problems. In the kitchen, the microwave oven uses electromagnetic radiation to heat and cook food. Astronomers analyze the composition of stars using spectroscopy. One of the questions raised in Station 19 asks for the composition of our atmosphere. One method to determine the composition is by analyzing the emission spectrum of air.

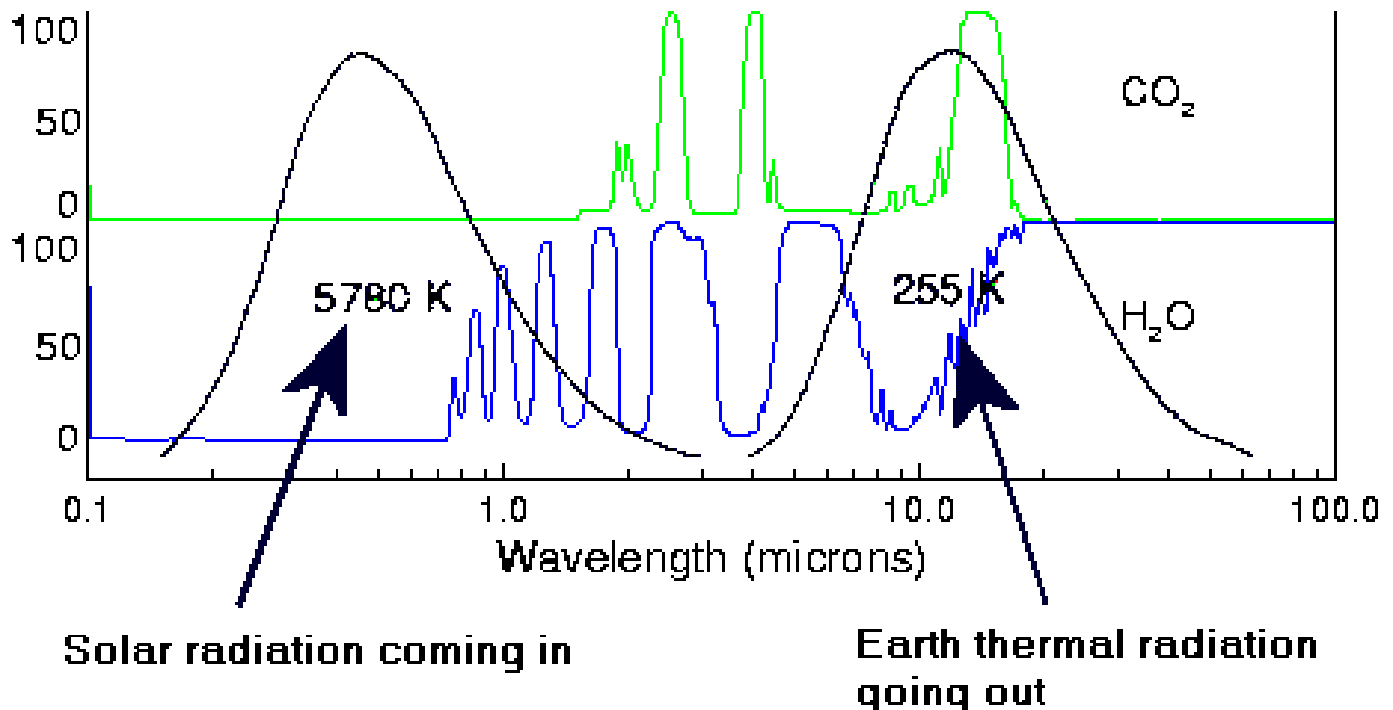


wave type	wavelength (nm)	energy (kJ/mol)	energy (cm <sup>-1</sup> )	transition
gamma	$10^{-1} - 10^{-3}$	$1.2 \times 10^6 - 1.2 \times 10^8$	$10^8 - 10^{10}$	electronic (ionization)
X-rays	$10 - 10^{-1}$	$1.2 \times 10^4 - 1.2 \times 10^6$	$10^6 - 10^8$	electronic (ionization)
far ultraviolet	$2 \times 10^2 - 10$	$6 \times 10^2 - 1.2 \times 10^4$	$5 \times 10^4 - 10^6$	electronic (ioniz., promotion)
ultraviolet	$4 \times 10^2 - 2 \times 10^2$	$3 \times 10^2 - 6 \times 10^2$	$2.5 \times 10^4 - 5 \times 10^4$	electronic (promotion)
bond energies		$1.5 \times 10^2 - 5.6 \times 10^2$		
visible	$7 \times 10^2 - 4 \times 10^2$	$1.7 \times 10^2 - 3 \times 10^2$	$1.4 \times 10^4 - 2.5 \times 10^4$	electronic (promotion)
infrared	$10^5 - 7 \times 10^2$	$1.2 - 1.7 \times 10^2$	$10^4 - 1.4 \times 10^4$	vibrational, rotational
<b>infrared (fundamental)</b>	<b><math>2.5 \times 10^4 - 2.5 \times 10^3</math></b>	<b>4.8 - 48</b>	<b>400 - 4000</b>	<b>vibrational</b>
microwaves, radar	$10^8 - 10^5$	$1.2 \times 10^{-3} - 1.2$	$10^{-1} - 10^4$	rotational
radio, mag. res., TV	$10^{12} - 10^8$	$1.2 \times 10^{-7} - 1.2 \times 10^{-3}$	$10^{-5} - 10^{-1}$	nuclear spin



Electromagnetic radiation can be characterized by its wavelength, frequency or energy. If one is known, the other two parameters can be easily calculated. As intuitively expected, the frequency and energy are proportional so the higher the frequency, the higher the energy. On the other hand, the wavelength is inversely related to energy so the longer the wavelength, the lower the energy. Radio and microwaves have very long wavelengths and are very low energy. Contrary to occasional lay language, a microwave oven does not “nuke” food. In reality, each microwave photon has a very low energy compared to the rest of the electromagnetic radiation spectrum used for analysis and other applications. The microwave oven functions by having a high volume of low energy waves absorbed that result in the heating of the sample.

Spectroscopy provides the scientific evidence that some gases trap infrared energy that otherwise would escape from the earth. Because of these Greenhouse gases led by water vapor, the earth is substantially warmer than it would be without these gases. As a result, the earth is a very hospitable place for life. However, human activities are changing the atmospheric composition and in particular have caused substantial increases in the amounts of carbon dioxide, methane and other infrared absorbing gases. As a result, the earth is warming in a way that poses many serious threats to life on earth. The science behind these comments is derivable from the chart below.



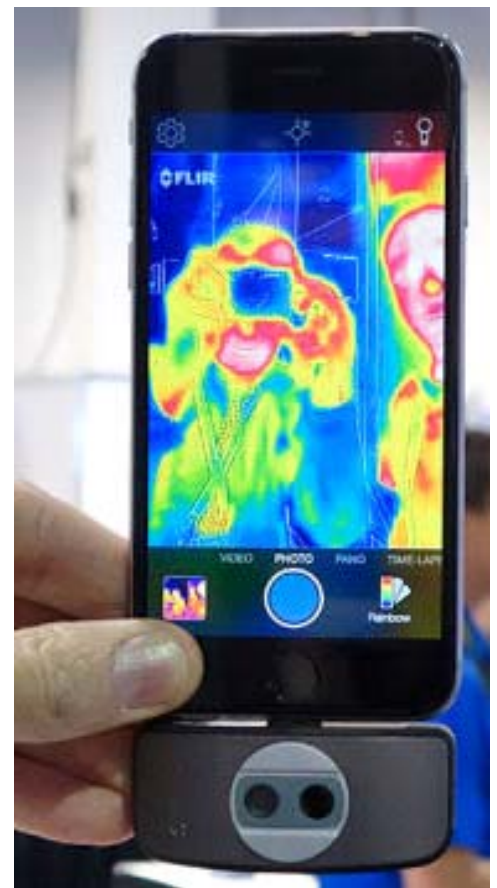
The chart above shows that water vapor absorbs a significant amount of the infrared radiation that ultimately results from energy conversions following the impact of solar radiation (uv, visible and ir) on the earth. Because CO<sub>2</sub> was a very small percentage (0.028% preindustrial) of the atmosphere, the prolific combustion of fossil fuels has raised the CO<sub>2</sub> content some 44% to 0.040% (current). While CO<sub>2</sub> remains a minor atmospheric constituent, the 44% increase is causing more escaping radiation to be trapped with a result that the earth is warming. The green curves above show that CO<sub>2</sub> absorbs in regions where water has low absorption. By increasing the CO<sub>2</sub>, the amount of absorbed outgoing ir radiation is increased. To minimize the damage, it is incumbent upon humans to begin an immediate and rapid phase out of fossil fuel combustion.

## STATION 20

### THERMAL IMAGING.

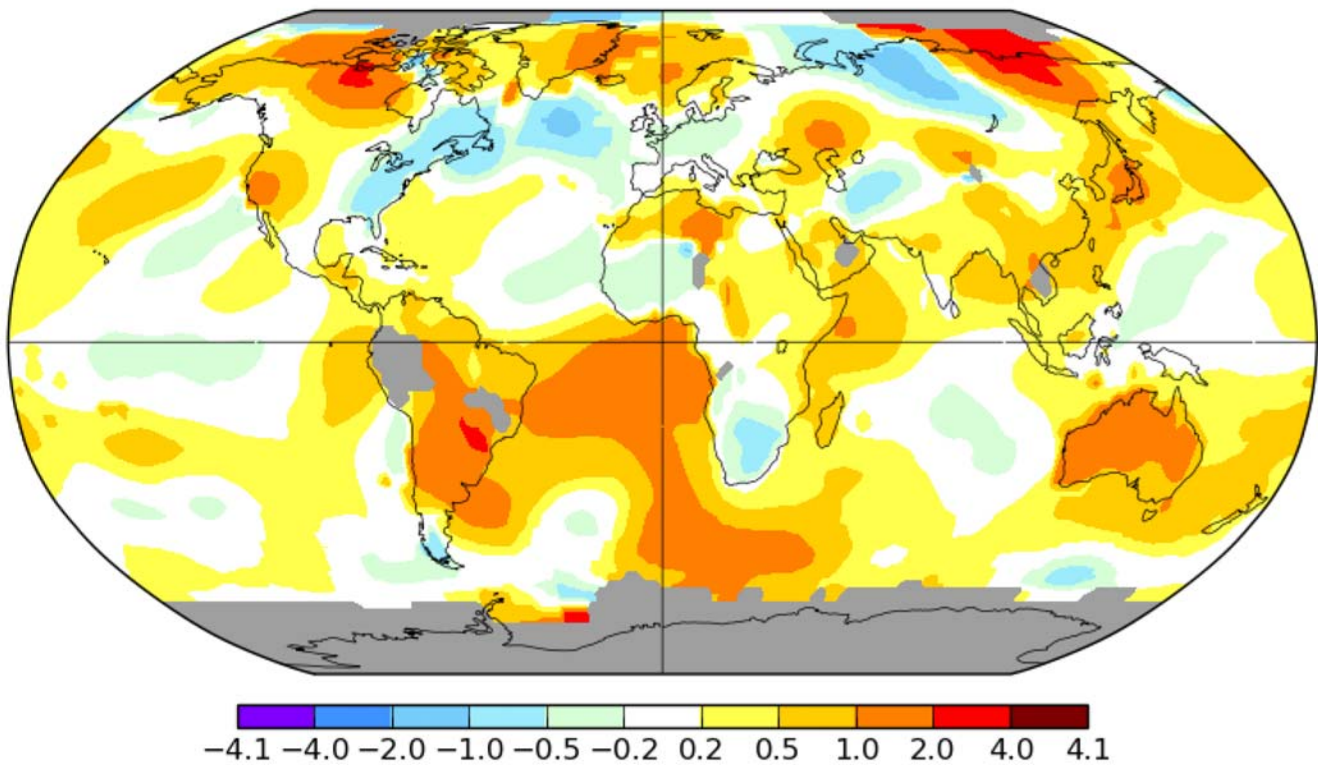
Accompanying thermal projections of the earth for four two year periods between 1972 and 2016 show that the earth is experiencing substantial warming. This is consistent with the evidence presented in Station 19.

An infrared camera is provided as part of this station that will enable you to take a thermal image of your face and upper body.

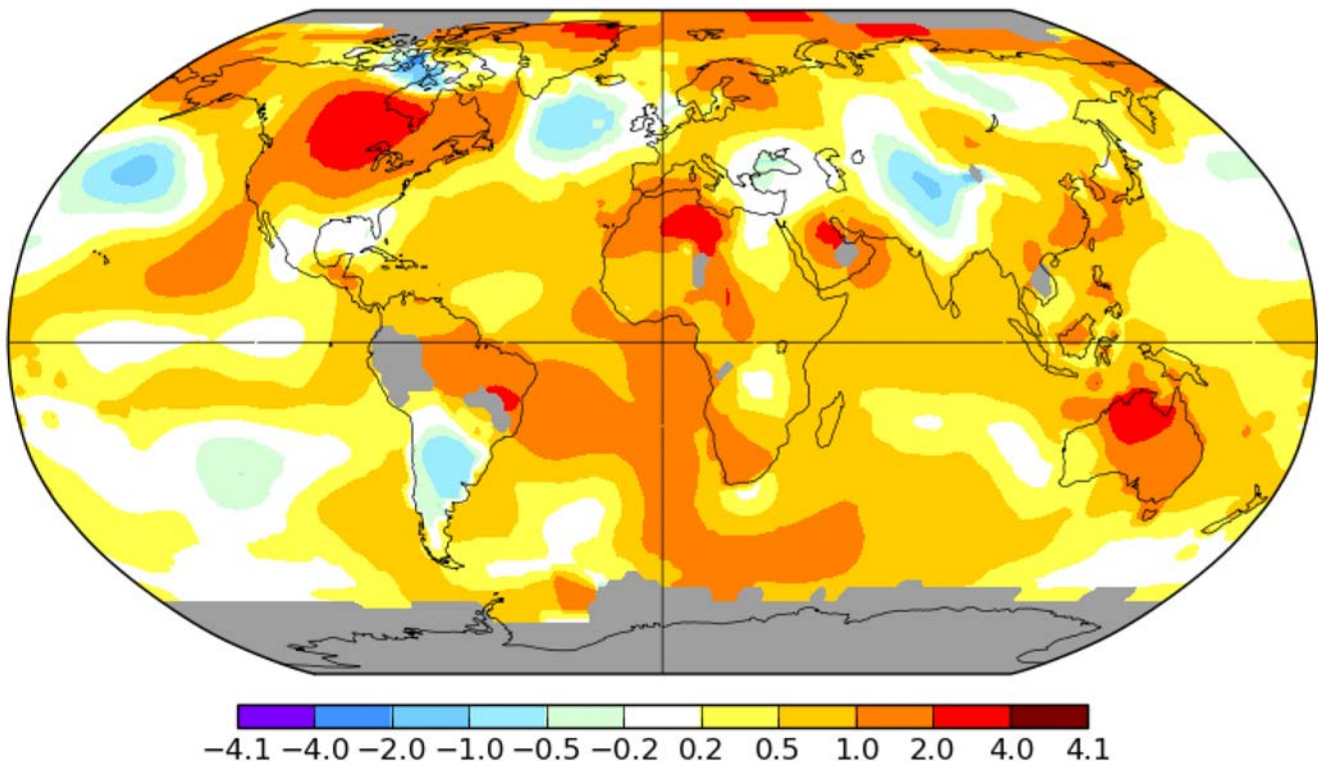


For global warming maps, see:  
<http://data.giss.nasa.gov/gistemp/maps/>

**Average global temperatures from May, 1972 - 1974,  
compared to a baseline average for the years, 1890 - 1920.**

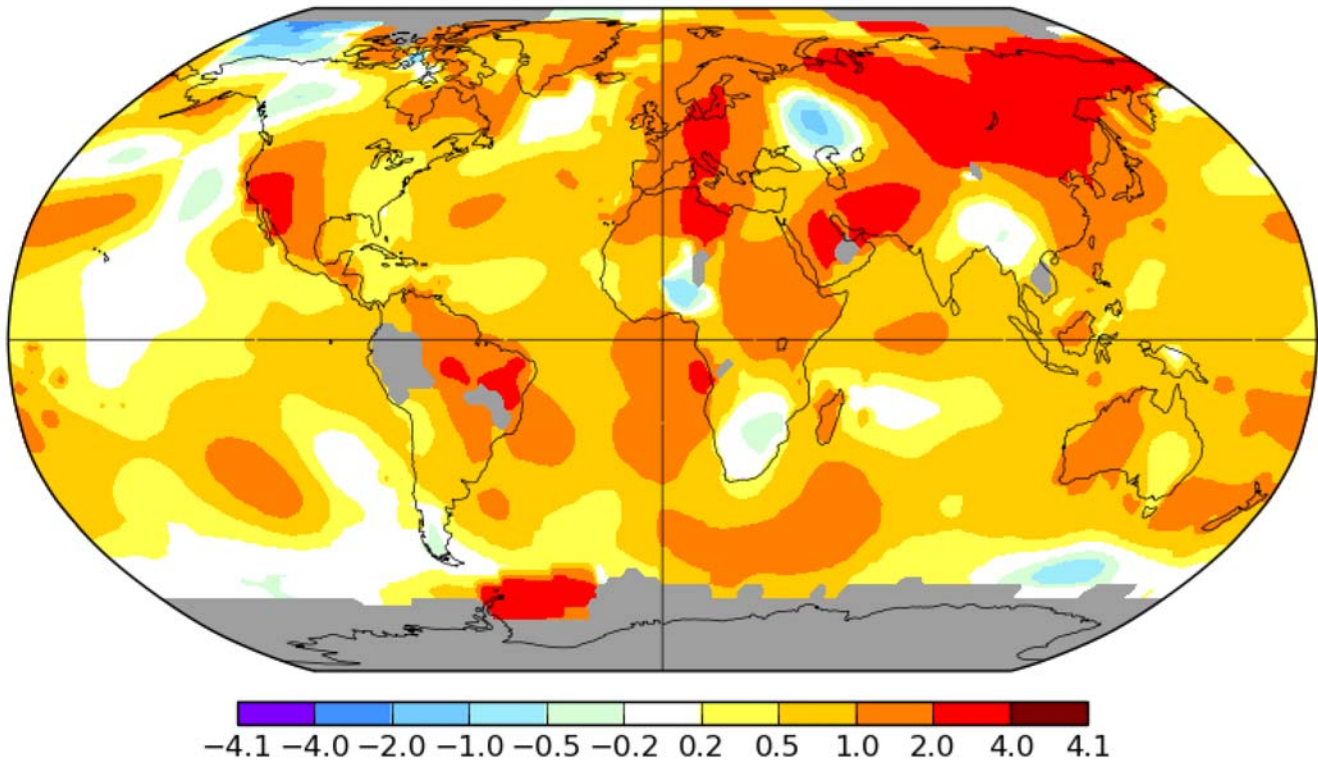


**Average global temperatures from May, 1986 - 1988,  
compared to a baseline average for the years, 1890 - 1920.**

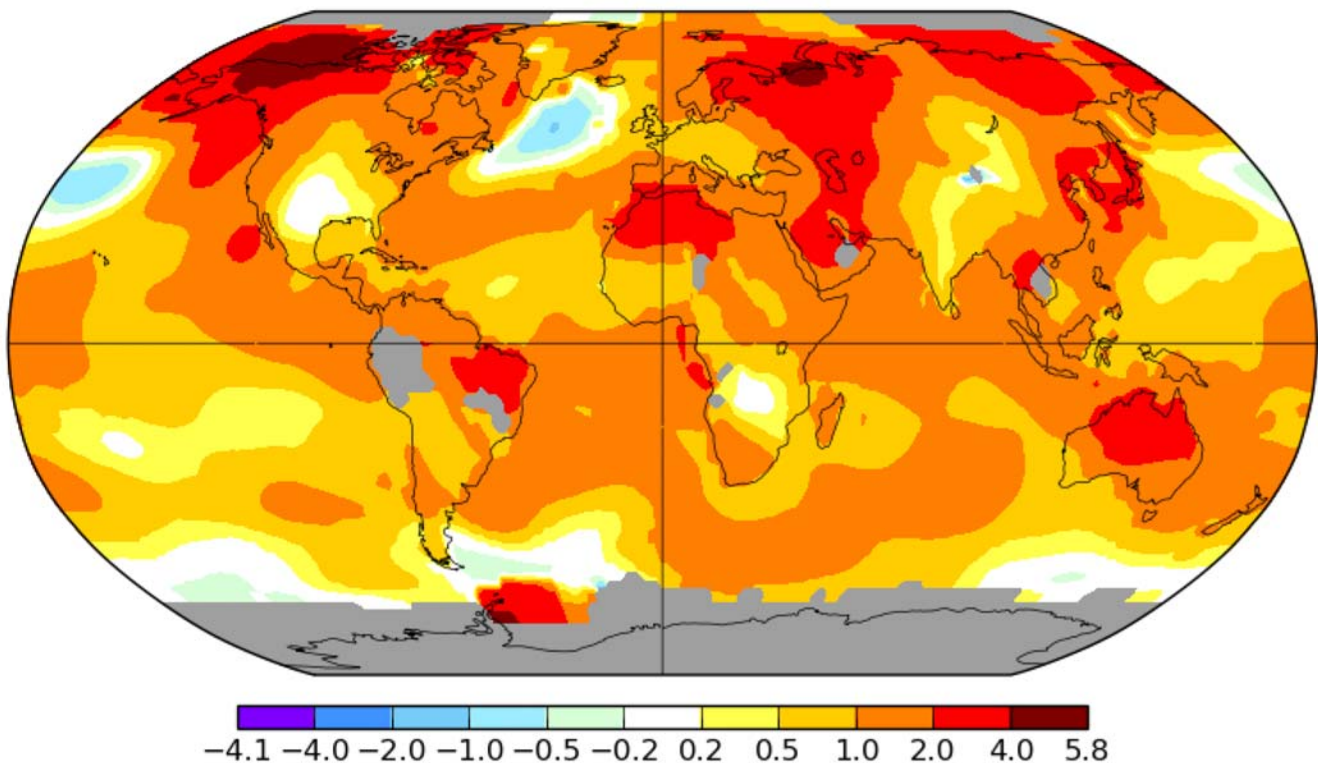




**Average global temperatures from May, 2000 - 2002,  
compared to a baseline average for the years,1890 - 1920.**

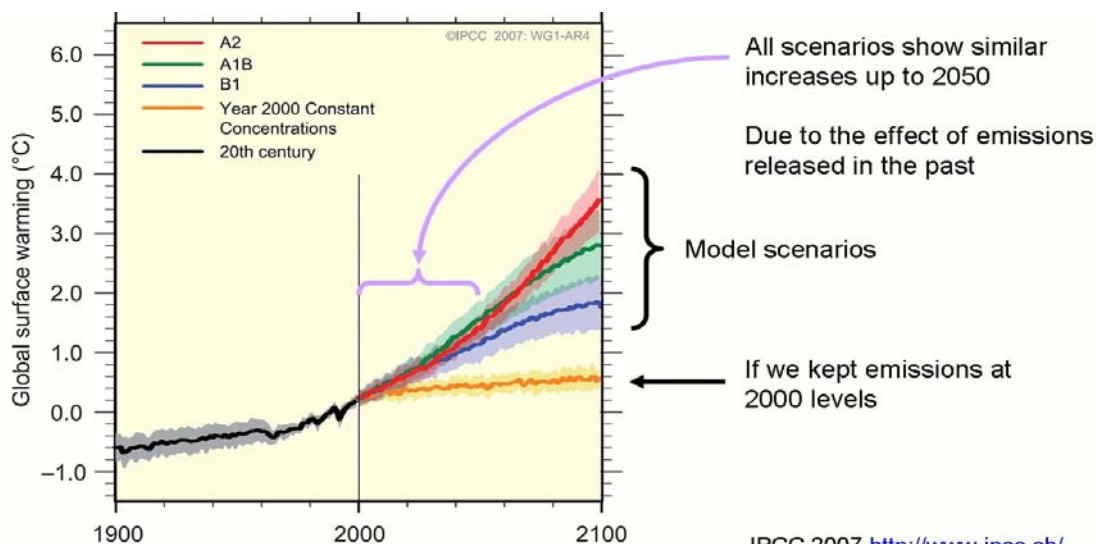
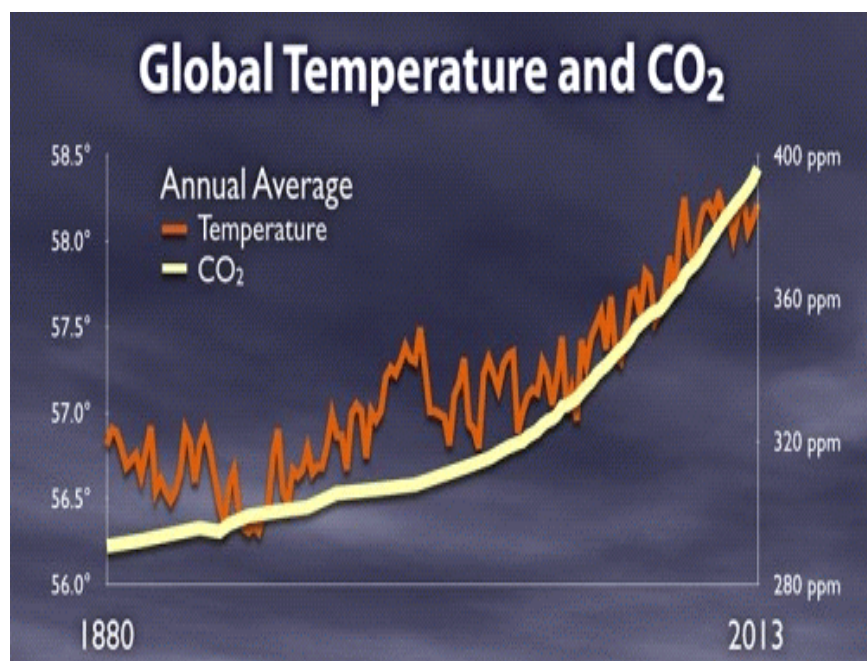
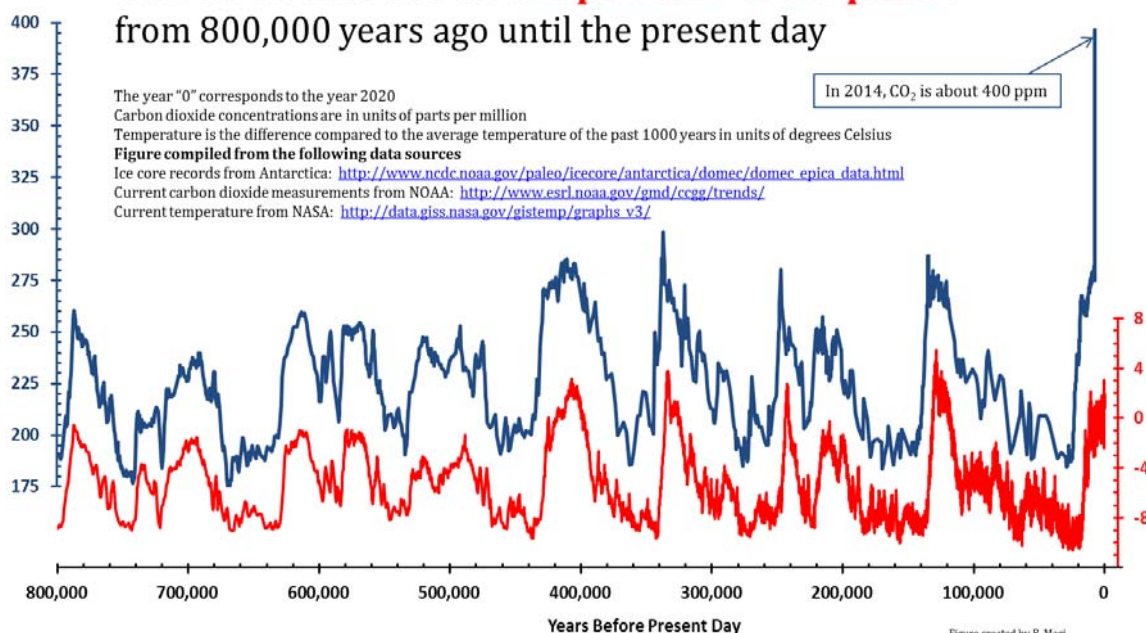


**Average global temperatures from May, 2014 - 2016,  
compared to a baseline average for the years,1890 - 1920.**



## Carbon dioxide and the temperature of our planet

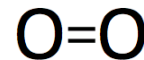
from 800,000 years ago until the present day





## From Station 18:

**Oxygen** is 21% of the content of our atmosphere. Oxygen exists as a diatomic molecule ( $O_2$ ) and is represented by the structure to the right (a Lewis structure with the electrons showing is not presented as the model is not consistent with the properties of  $O_2$ ). There are three formulas of oxygen that can exist -  $O$ ,  $O_2$  and  $O_3$  (ozone).  $O$  and  $O_3$  are very reactive and toxic. It is difficult to imagine a type of life that could exist without  $O_2$ . Ozone is produced as a result of combustion processes and is a primary and dangerous constituent of smog.



Skeletal structure of  $O_2$ .

**Ozone** ( $O_3$ ) does play a very important role in the upper atmosphere by filtering out substantial amounts of harmful UV radiation. In the 1970's, chemists provided evidence that freons used as spray propellants and in air conditioning units were causing a depletion of the very vital ozone layer. Fortunately, global governmental action has substantially decreased the use of the harmful freons and the ozone layer is slowly recovering from the hazardous decrease (lower ozone results in more skin cancer). Many people connect the ozone depletion issue with climate change. However, the issues are independent but freons do cause both. The global community needs to understand the importance of the precedent set by the global response to the ozone issue and take similar action to remedy the even more serious climate change issue.

