TEST ON THURSDAY
QUESTIONS FOR POINTS
Q: FILL IN THE BLANKS

- A acre-feet of water is about __________ gallons and is enough water for ____ families of _____ for a year.
Q: FILL IN THE BLANKS

• What is a general truth about rainfall and variability?
Q: FILL IN THE BLANKS

• The ________ protocol regulated/banned the use of ________, which was destroying the ozone layer.
GLOBAL WARMING
GOALS

- Convince you that global warming is occurring
- Convince you that man is causing some of the warming
- Show how humans are changing the climate
OUTLINE

• Global Warming
• Natural Causes of Climate Change
• Manmade Causes of Climate Change
I. DIRECT MEASUREMENTS SHOW TEMPERATURE HAS INCREASED IN THE PAST 100 YEARS
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![Graph showing surface and satellite temperatures with a trend line indicating increase over time.](image)
II. ARCTIC ICE LEVELS ARE DECREASING

Ice caps are shrinking
III: SEA LEVELS ARE RISING

• Sea level rise is caused by thermal expansion - water expands a little bit when it is heated

• Sea level rise is also caused by melting ice and glaciers
Sea Levels are rising
II. PROXY MEASUREMENTS SHOW WE ARE INCREASING TEMPERATURES FASTER THAN ANY TIME IN HISTORY
II. PROXY MEASUREMENTS SHOW WE ARE INCREASING TEMPERATURES FASTER THAN ANY TIME IN HISTORY

Tree rings show historical temperatures before instrumentation
Ice core data show CO2 levels from thousands of years ago that can be used to infer temperatures.
Temperatures rising faster than anytime in measurable history

![Reconstructed Temperature Graph](image)

- Medieval Warm Period
- Little Ice Age
- 2004 *
Fact: Temperatures rising faster than anytime in measurable history.
CAUSES OF TEMPERATURE CHANGES
Natural
Sun's energy output varies over time
Number of sunspots indicate solar activity
Prior to 1980, sunspot number (solar activity) correlated well with global temperatures.
But since 1980, no longer correlated - we are at high temperatures even though solar radiation is low.
CONTRIBUTION OF SOLAR VARIATION

• Solar variation is does not account for observed temperature change

• We have measured that about 1361 watts per square meter of solar power reaches Earth

• When sun is active, an addition 1.3 watts reaches Earth

• This can only account for a 0.15 degree change in temperature
VARIATION IN ORBIT/TILT OF EARTH
Volcanoes - releases aerosols into the atmosphere
MOUNT PINATUBO

• Erupted in 1991 - released 10 cubic km of stuff into the air including sulfur

• Due to sulfuric acid haze, light is blocked from hitting the surface of the earth

• Decrease in global temperatures of about 0.4 degrees C (0.7 degrees F)
EL NINO/LA NINA

- El Nino: Warming of temperatures in the Equatorial Pacific
- La Nina: Cooling of temperatures in the Equatorial Pacific
- A periodic climate pattern that occurs across the tropical Pacific Ocean every 5 years
EL NINO

• El Nino is defined by prolonged differences in Pacific Ocean surface temperatures (at least 0.5°C)

• Happens every 2-7 years (average 5 years)

• Lasts 9 months to 2 years
MORE HURRICANES?

• More/stronger hurricanes is consistent with global warming

• But we need decades of data to confirm a trend - it is probably premature to conclude that global warming is the major cause

• Global Warming => More Hurricanes
MORE QUESTIONS FOR POINTS
Q: NAME 4 PIECES OF EVIDENCE THAT SHOW TEMPERATURES ARE INCREASING

- Direct Measurement
- Increased Sea Levels
- Decreased Ice Surface Area
- Measuring tree rings and ice cores show us that temperatures are increasing at a very fast rate
Q: NAME 4 CAUSES OF NATURAL TEMPERATURE CHANGE

• Solar Variation - Solar output changes and effects temperature on Earth

• Cycles - Earth’s tilt and wobble causes temperature change over thousands of years

• Volcanoes - Releases soot and ash that blocks solar radiation lowering temperature

• El Nino/La Nino - Changes surface temperature over the Pacific
WHY ARE THEY INSUFFICIENT TO EXPLAIN CURRENT TRENDS IN TEMPERATURE CHANGE?

- Solar Variation
  - Since 1980, the temperature remains high despite low solar activity

- Orbital cycles
  - Time scales are different

- Volcanoes
  - Causes a decrease in temperature, not an increase

- El Nino/La Nina
  - El Nino/La Nina - Cycles between hot and cold, doesn’t stay hot
CAUSES OF TEMPERATURE CHANGES

Manmade
Some argue that man isn’t contributing to the change in global temperatures.

If this was true, you have to believe that the unprecedented rise in temperature over the past 120 years is a mere coincidence.

If you know that the Earth’s temperature is rising, you should be skeptical of this claim.
PUBLIC VS SCIENTIFIC BELIEF

• 97-98% of the active climate researchers (N=908) agree that man is contributing significantly to global warming

• The more a scientist knows about climate change, the more they believe that man is contributing significantly to it

• Only 48% of the public believe the same
From PNAS 2010 Abstract: Here, we use an extensive dataset of 1,372 climate researchers and their publication and citation data to show that (i) 97–98% of the climate researchers most actively publishing in the field support the tenets of ACC outlined by the Intergovernmental Panel on Climate Change, and (ii) the relative climate expertise and scientific prominence of the researchers unconvinced of ACC are substantially below that of the convinced researchers.

ACC = anthropogenic climate change
MAN-MADE GLOBAL WARMING IS COMPLEX

• Decrease in temperature: Global Dimming
• Increase in temperature: Greenhouse effect
• Positive and Negative feedback loops
GLOBAL DIMMING

- Release of particulates in the air
  - Blocks sunlight
  - Lowers surface temperatures
- About 4% reduction of solar irradiance
- Causes global cooling - masks some effect of global warming
EARTH’S ENERGY BALANCE

- Energy In = Energy Out
- Energy In: Solar radiation
  - 30% Reflected back into space
  - 70% Absorbed by atmosphere and surface
- Energy out: Heat lost to space
  - 70% Heat lost to space
1. Solar radiation passes through the clear atmosphere.
   Incoming solar radiation: 343 Watt per m²

2. Net incoming solar radiation: 240 Watt per m²

3. Some solar radiation is reflected by the atmosphere and earth’s surface.
   Outgoing solar radiation: 103 Watt per m²
   Net outgoing infrared radiation: 137 Watt per m²

4. Solar energy is absorbed by the earth’s surface and warms it...
   ... and is converted into heat causing the emission of long wave (infrared) radiation back to the atmosphere.
   Net outgoing infrared radiation: 137 Watt per m²

5. Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules. The direct effect is the warming of the earth’s surface and the troposphere.
   Surface gains more heat and infrared radiation is emitted again.

6. Some of the infrared radiation passes through the atmosphere and is lost in space.

Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA). Johnsson. Climate change 1990. The science of climate change, contribution of working group 1 to the second assessment report of the Intergovernmental panel on climate change.
• 70% of the energy reaching Earth goes into heating the planet
• It is all radiated back into space
• But the time the energy stays on Earth increases temperatures
• The longer the energy stays - hotter it gets
GREENHOUSE EFFECT

- Greenhouse gases in the atmosphere reflect heat back to the Earth instead of allowing heat to go into space
- Greenhouse gases include carbon dioxide, methane, and water vapor
GREENHOUSE GASES

- Carbon Dioxide
  - Consumed by plants
  - Released by consumption of fossil fuels
Trends in Atmospheric CO₂ & Global Surface Temperature

Period: 400k years

- Antarctic Surface Temperature
- Pre-industrial atmospheric CO₂
- Humans contribution atmospheric CO₂

Thousands of years before present

Atmospheric CO₂ (ppm)

Temperature Degree C

Data from:
- CLIMAP Project Members, CLIMAP:侮辱年scale 400 kyr carbon dioxide history, Nature 279, 329-332 (1979). doi:10.1038/279329a0
Carbon Dioxide Variations

The Industrial Revolution Has Caused A Dramatic Rise in CO₂

Ice Age Cycles

CO₂ Concentration (ppmv)
GREENHOUSE GASES

- Methane
  - Released by animals
  - Increased due to domestication of livestock
- Nitrous Oxide
- CFCs
- Water Vapor
GREENHOUSE GASES

- Carbon Dioxide
- Nitrous Oxide
- Methane
- CFC-12 and CFC-11
SUMMARY OF GREENHOUSE EFFECT

- Energy trapped by greenhouse gases (like CO2, Methane, Water Vapor) in the atmosphere
- Causes energy to stay on Earth longer
- Increases temperature
NEGATIVE FEEDBACK LOOP

- Increased temperature increases algae growth in the ocean and plant growth on land
- Depletes atmospheric CO2
POSITIVE FEEDBACK LOOPS

• Increased temperature causes soil organisms to respire (breath) faster
• Faster respiration converts more soil organics to CO2
• More CO2 = higher temperatures
POSITIVE FEEDBACK LOOPS

• Increased temperature causes glaciers to melt
• Loss of reflective surfaces leads to more absorption of sunlight
• More absorption leads to higher temperatures
• Also releases CO2 that’s stored in the ice
POSITIVE FEEDBACK LOOPS

- Increased temperature increases water vapor in the atmosphere
- Which increases the green house effects
WHY DENY WARMING?

• Money - Many multi-billion dollar industries release greenhouse gases, any regulation may hurt profits. It costs capital to change our use of fossil fuels.

• Some claim that global warming is a hoax brought about by Green industries

• Politics - accepting global warming is man-made makes us responsible for problems that arise from global warming

• Complexity - many positive/negative feedback loops makes it difficult to understand and predict

• Distrust of scientists
NAME 2 MAN-MADE CAUSES OF TEMPERATURE CHANGE

• The Greenhouse Effect - Greenhouse gases trap heat on the Earth

• Global Dimming - Increased particulates in the air blocks light from hitting the surface the Earth
4 FEEDBACK LOOPS INVOLVING GLOBAL WARMING

- Higher temperatures increase algae and plant growth which decrease CO2 levels
- Higher temperatures lead to the melting of polar ice caps which decrease planetary albedo and also release trapped CO2
- Higher temperatures increases respiratory rates which increases CO2
- Higher temperatures increase water vapor in the air which is a greenhouse gas
EFFECTS OF WARMING
Global Warming Predictions

2070-2100 Prediction vs. 1980-1990 Average

Based on HadCM3

Temperature Increase (°C)

0 1 2 3 4 5 6 7 8
Projected Change in Precipitation by 2080 - 2099

Winter

Spring

Drier

Wetter

Percent Change
Projected Patterns of Precipitation Changes

-20 -10 -5 5 10 20
EFFECT OF WARMING

• Glacier’s melt - increased sea levels threaten coastal cities
• Increased intensity of storms
• Effect food supply
• Less snow, drying of soil will decrease stream and river flow
ECOLOGICAL EFFECTS

• Spring arrives up to two weeks earlier than 3 decades ago
• Coral reefs are adversely effected by temperature
• Species migrate north to avoid heat
• Increased migration increases spread of disease
• Tropical diseases like malaria can spread
• Global warming is real and is happening now.
• Warming is measurable directly and indirectly.
• Warming is occurring faster than any other time in history.
• Solar variations, orbital cycles, volcanoes, and the El Nino cycle all causes changes in temperature.
Humans are contributing to the global temperature increase.

Greenhouse gases trap heat in atmosphere and increase temperatures.

Many positive/negative feedback loops make it more complex.

But global warming is definitely happening. And man is contributing to it.
• Test on Thursday!