Class Sessions #2

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# Climate change science (cover this lecture over course of this and next class)

# Basics of Earth’s climate = the **average** weather.

## Atmosphere keeps planet warmer than it would be without it

## Weather is chaotic, climate is not.

## Why can we predict climate but not weather? Can predict June “climate” but not June weather

## Know Eugene is wetter than Phoenix even though may rain in either & can’t predict tomorrow perfectly

## Always easier to predict an average: “Climate is what you expect, weather is what you get.”

# **Is the climate changing?** First of two related questions and answers

## Temperatures as measured are increasing over time, with various measurement types consistent with each other: thermometers / ice cores / corals / tree rings / satellites / land and ocean temps /

### Thermometer records for ~150 years -- increasing

### Tree rings

### Ice cores: “Chemical composition of the ice [fraction of hydrogen and oxygen isotopes] can be used to infer air temperature around the glacier when the snow fell, as can variations in the size and orientation of ice crystals. Small air bubbles trapped when glacial ice formed preserve a snapshot of the chemical composition of the atmosphere at that moment” {Dessler, 2010 #6600, 75}.

### Corals

### Ocean sediments

## Other indicators show warming has occurred: precipitation changes / glaciers / sea level rise / Arctic ice / date of river-ice breakup / extreme climate events

### CanNOT attribute single events to climate change but can attribute probability shifts to it

## Responses of different animals and plants: bird migration days / plant blooming days

## **Amount** of warming appears to be outside natural variation

## **Rate** of warming appears to be faster than natural variation

# **Are humans the cause of the changes we are seeing?** Second of two related questions and answers

## Physics and chemistry of planet temperature known

### Basic physics and chemistry say more GHGs, more temperature

### Record shows CO2-temperature correlation

### Three main gases keep earth warm: CO2, CH4, and N2O plus H2O: influence can be shown in lab

## Earth is in equilibrium and small changes can get it out of equilibrium

### CO2 and CH4 are VERY small fraction of atmosphereN2: 78%; O2: 21%; Ar: 1%; CO2: 0.04%; CH4: 0.0002%

### Small changes in inputs can make big changes in outputs.

#### Delicate balance is in equilibrium: 500 pounds on each side, grain of sand can unbalance.

#### Human body: 5 beers = (5\* 12 \* .05) 3 ounces of alcohol can influence a 2400 ounce person (150 pounds)

## See increases in atmosphere of the chemicals that are known to increase warming

### CO2

#### Atmospheric concentrations over past 10,000 years between 260 and 280

#### Currently at about 400 and on a steady trajectory upward in last 60 years (Mauna Loa)

### CH4

#### Atmospheric concentrations before 1800 at 0.8 ppm

#### Began increasing in 1800 and now at 1.75 ppm (more than 2x)

### No other explanations of these changes

## Can account for the human activities that are putting these chemicals into the atmosphere

### Since industrial revolution in 1860s, humans have dumped large quantities of CO2, CH4, and N2O into atmosphere as a byproduct of fossil fuel burning, deforestation, livestock and rice cultivation

### Human GHG emissions: up 70% from 1970-2004

### 75% of problem: Carbon Dioxide (CO2): Fossil fuel use for transport, electricity, heating, cooling, manufacturing; Deforestation

### 15% of problem: Methane (CH4): Livestock and manure; Rice cultivation

### 8% of problem: Nitrous Oxide (N2O): Agriculture fertilization

## Temperature changes coincide with concentration and human activity increases

### Glacier record – decline starts in 1850

### Sea level -- increase starts in 1850

### Since 1900:

#### 1.5F (0.7C) rise in global surface air temp

#### 30% increase in CO2

#### 150% increase in CH4 (methane)

### Happening on HUMAN timescales, not ecological ones

#### If earth were 100 years old

#### Then man emerges ~ 1 day ago

#### Recorded history started 2 hours ago

#### Industrial revolution started 2 minutes ago

## Models match data only if natural factors and human factors included

### Five **natural** causes of climate change - but none correspond to observed change

#### Tectonic processes - Pangea and all that change global climate -- too slow

#### Variation in Earth’s orbit -- tilt and apogee, perigee, and elliptical shape -- too slow

#### Volcanic eruptions -- eruptions don’t correlate with temp changes

#### Variation in Sun’s energy output -- solar energy would warm whole atmosphere but stratosphere is cooling and don’t correlate with temp changes

#### Internal variability of climate system -- don’t correlate with temp changes

### Many causes of greenhouse effect but few non-human causes of ***increase*** in greenhouse effect

### Computer models only match observations of temperature when BOTH natural and human forcings are included.

## Overall: Correlation of levels with human activities: Humans emitting more GHGs, atmospheric concentrations going up, temp going up as predicted, and other causes can be excluded.