

## Day 1, AM: Radiation (Atmospheric Greenhouse Effect)

### *Key Points*

Radiation is an important means of energy transfer. Understanding radiation means understanding some properties of electromagnetic waves and how they interact with matter.

Some molecules in the atmosphere absorb and re-radiate thermal radiation. The radiation is absorbed and reemitted at every level. What we feel at the surface is a weighted average of the “stack”. The *atmospheric greenhouse effect* is about the vertical redistribution of heat in the atmosphere.

### *Outline of the Session*

#### **8:30 Introductions and Overview**

- Introductions / Teachers / Course presenters (10 minutes)
- Overview of course structure / assignment / credit / instructional approach / mixing / practical details (All - 10 minutes)

#### **8:45 Engage / Explore / Explain: What do the infrared thermometers measure?**

- “Leslie cube”: Measure temperature of warm pop cans at different spots.
- Explain: Thermal radiation

#### **9:15 Engage / Explore / Explain: Energy & Radiation**

- Explore: Rainbow glasses & the electromagnetic spectrum
- Quick calculation: Peak wavelength of incandescent bulb?
- Thermal radiation and the body: A quick calculation.
  - What is your body temperature in Kelvin?
- Explain: How do satellites take data?
- Explore: *Why does it get colder on clear nights than cloudy nights?*
  - Measurement of sky temperatures, discussion.
- Thermal cameras: What do these tell us about the world? What surprises do we find by using them?

#### **10:15 Break**

#### **10:30 Engage / Explain: Seasons**

- Engage: Seasons demonstration
- Explain: Seasons

### **10:45 Engage / Explore / Explain: Radiation and the Earth**

- Explore: *How does the atmosphere keep the earth warm?*
- Explain: Atmospheric Greenhouse Effect
  - Calculations: Do the two different calculations
- Kinesthetic Activity: *Long and Short of It.*

### **11:45 Writing Time**

- In journals, answer the following questions:
  - ▶ What are the main lessons from this session's activities and discussions?
  - ▶ What questions or uncertainties about this material do you still have?
  - ▶ What did this session make you wonder about—what questions did it raise?
  
- **Evaluate:**  
**QUESTION: Why is August hotter than June?**

### **12:00 Lunch**

## **Day 1, PM: Basic Climate Change (enhanced atmospheric greenhouse effect, water vapor feedback)**

### ***Key Points***

A given distribution of so-called greenhouse gases (most importantly CO<sub>2</sub> and H<sub>2</sub>O) in the atmosphere produces a certain climate equilibrium state, which may loosely be described by "energy in = energy out". Changes to the greenhouse gases lead to changes in thermal radiation in and out of the climate system. These changes will occur until a new equilibrium state is reached and this requires a change in temperature. Some changes in the climate system lead to further changes in the radiation that drives the changes in the first place - this is a feedback.

### ***Outline of the Session***

**1:00 Question Time:** Get to know the presenters, participant questions.

**1:10 Engage / Explore / Explain: Enhanced atmospheric greenhouse effect**

- Explore: *Why does it get colder on clear nights than cloudy nights?*
  - Measurement of sky temperatures (save for later)
- Revisit glass plates, but explore more
  - Question: Will adding plates affect the temperature of the lower plate? Why?
  - Question: How will the temperatures vary if you turn the stack upside down?
- Historical piece: Fourier and Tyndall
- Explore/Explain: *What is a model?*
- Extend: What happens if you double the amount of CO<sub>2</sub> in the model?
- Discussion: Why is Arrhenius's number off for doubling of CO<sub>2</sub>?

**2:30 Break**

**2:45 Engage / Explore / Explain: Water Vapor**

- Explain: Size comparison of water vapor, mist, and cloud droplet
- Vapor Pressure: *Why can warm air "hold" more moisture than cold air?*
- Question: Which place has more water vapor?
- Explain: Relative Humidity

**3:25 Engage / Explain: Feedback with inflatable globe and ping pong balls**

- Interactive feedback demo
  - Positive feedback versus negative feedback
- Explain: Importance of negative feedback
- Discussion: What are real world examples of feedback?

**4:00 Writing Time**

- In journals, answer the following questions:
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**4:15 Evaluate**

- **QUESTION:** If the Earth was at the same distance from the sun as Venus, would they both have the same surface temperature? Average surface temperature of Venus is 730 K (854 F).

**5:30 Social Event**

## Day 2, AM: Stability/Buoyancy, Convection, Clouds

### *Key Points*

The atmosphere is primarily heated from the surface (with the surface being heated up by the sun), but it cools from the top. Over the course of a day, energy must be transported upward, by rising air. This vertical motion of air explains the changes we see in the weather over a typical summer day.

### **8:30 Question Time**

### **8:45 Engage / Explore / Explain: Pressure, Temperature, and Force Balances.**

- Engage: Bubbles in aquarium of CO<sub>2</sub>
- Engage: What happens if you put a balloon animal in liquid nitrogen?
- PhET online experiment: [Gas properties](#)
- Discussion: Molecules in a box vs. Molecules in a balloon
- Revisit PhET model
- Explain: Hydrostatic force balance
- Explore: *If hot air rises, why is cold in the mountains?*
- Explain: Adiabatic expansion/compression (dry adiabatic lapse rate)

### **9:45 Break**

### **10:00 Engage / Explore / Explain: Clouds and Vertical Motion**

- Creating Clouds: *Can Cities Affect the Weather?*
- Explain: Weather station data (humidity and temperature)
- Heat packs: *How Can Freezing Make Something Warmer?*
- Explain: Latent heat and phase changes
- Blowing on your hand: *How Do Clouds Keep the Air Warmer?*
- Spark online experiment: [Air Parcel](#) (dry and wet parcel)
- Explain: Moist adiabatic lapse rate

### **11:10 Science in History: Discovery of the Stratosphere**

- Interactive evaluation of sounding data

### **11:35 Writing Time**

- In journals, answer the following questions:
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### **11: 50 Evaluate: Clouds and Vertical Motion**

- What happens to the moist adiabatic lapse rate as you go high up in the atmosphere?
- Why do cumulus clouds have well defined flat bottoms, but variable cloud top heights?
- If the air outside an airplane in flight is cold, why do they need to use air conditioning on the airplane?

### **12:00 Lunch**

## **Day 2, PM: Force balances, Geostrophic Flow, Cyclones, Highs and Lows**

### ***Key Points***

Differences in temperature between different places on our planet cause pressure differences, and these in turn produce winds. But this situation is complicated by a simple fact: the earth rotates. The so-called geostrophic force balance arises, which combines the forces due to pressure differences and Earth's rotation, and which is most important for the broader scale weather features, such as high and lows.

### ***Outline of the Session***

**1:00 Question Time:** Get to know the presenters, participant questions.

**1:10 Extend / Explain: Thunderstorms, Supercells, Tornadoes**

- Video/Discussion: How do thunderstorm form?
- Explain: Thunderstorms, microbursts, lightning, and thunder
- Engage: Angular momentum demo
- Video/Explain: Supercells

**1:50 Focus Group Discussion**

**2:00 Engage / Explore / Explain: Force Balance and Coriolis Effect**

- Engage: Spinning versus non-spinning tank
- Spark online experiment: [Water tanks](#)
- Explain: Winds (motion due to pressure differences)
- Question: Does pressure always move from high to low? (What is the mysterious force?)
- Discussion: Force balance and steady flow
- Explore: Hover puck on table
- Explain: Force balance between pressure gradient force and Coriolis force
- Coriolis Circle (non-rotating vs. rotating): *Why doesn't the wind blow from high to low pressure?*
- Explain: Frame of reference videos (rotating puck)
- Explore: Conservation of angular momentum

**3:00 Break**

**3:15 Evaluate:** Weather map

**3:30 Extend & Evaluate:** Hurricanes, [Jupiter's Red Spot](#), and Asian Monsoon

- Which Way Does the Wind Blow?

**4:00 Writing Time**

- In journals, answer the following questions:
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  - ▶ What did this session make you wonder about—what questions did it raise?

**4:15 Time allowing: Surface force balance**

- Question: What happens to the force balance when you add friction?

**4:30 Adjourn**



## **Day 3, AM: General Circulation (Hadley Cell, Ferrel Cell), El Niño/La Niña, Polar Vortex**

### ***Key Points***

If you look at net planetary energy inflows and outflows, the earth warms at the equator but cools at the poles. And so energy must be transported—by moving air and by ocean currents—from the equator to the poles. The poleward motion of matter and energy combined with the rotation of the globe leads to broad patterns in the earth’s weather—climate zones.

### **8:30 Question Time**

### **8:45 Engage / Explore / Explain: General Circulation (Hadley cell & Ferrel cell)**

- Engage: Fast rotating tank demo (What is happening?)
- Explore non-rotating circulation: *Cold Front, Hot Front* - start experiment
- Engage: Large scale spin tank (part 1 - not spinning)
- Explain: What makes the wind blow?
- Discussion: What is happening in *Cold Front, Hot Front* tanks. How does this relate to pressure differences?
- Engage: Large scale spin tank (part 2 - slow spin)
- Explain: Hadley cell
- Engage: Fast spin tank video
- Explore: Small scale spin tanks
- Explain: Midlatitude weather, Ferrel cell

### **10:15 Break**

### **10:30 Engage: Discovery of the trade winds**

### **11:00 Evaluate: General circulation**

- Discussion: How do you explain the seasonal patterns?

### **11:10 Explain: El Niño/La Niña**

### **11:30 Writing Time**

- In journals, answer the following questions:
  - What are the main lessons from this session’s activities and discussions?

- ▶ What questions or uncertainties about this material do you still have?
- ▶ What did this session make you wonder about—what questions did it raise?

**11:45 Extend / Explain / Evaluate:**

**Why do we have an ozone hole over the Antarctic, but not over the Arctic?**

- Question: What is the polar vortex?
- On Earth
- On Saturn
- Discussion: How to teach difference between global warming and ozone hole.

**12:00 Lunch**

## **Day 3, PM: Weather vs. Climate (Chaos), Natural versus Anthropogenic Climate Change; Ozone Hole**

### ***Key Points***

If scientists can't predict the weather 10 days from now (and never will be able to), how can they predict climate 100 years from now? Answering this question means understanding the difference between weather and climate and understanding how we can model the earth's climate and how it is changing. Moreover, it is important to distinguish between natural climate variability from year to year and anthropogenic (human-induced) climate change over several decades up to centuries.

### ***Outline of the Session***

**1:00 Question Time:** Get to know the presenters, participant questions.

**1:15 Engage / Explore / Explain: Weather vs. Climate**

- Engage: Double Pendulum demo
- University of Toronto online: [Three body problem and the discovery of chaos](#)
- Explain: Initial conditions and boundary conditions
- Discussions: What is an initial condition and a boundary condition in reference to climate?
  - Will cutting down one tree make a difference? How about two? How about a whole forest?
- Explore: [Spreadsheets and Chaos](#)

**2:15 Engage / Explain: Natural versus Anthropogenic Climate Change**

- Explain: Brief climate through the ages
  - Natural climate variability
    - Volcanos
    - Solar activity
    - El Nino/La Nina
- Discussion: Importance of feedbacks
  - Water vapor
  - Ice/albedo

- Ocean carbon cycle
- Stefan-Boltzmann
- Clouds
- Explain: Future climate change

**2:45 Curing the Ozone Hole**

**3:00 Writing Time**

- In journals, answer the following questions:
  - What are the main lessons from this session’s activities and discussions?
  - What questions or uncertainties about this material do you still have?
  - What did this session make you wonder about—what questions did it raise?
  - What are your top concerns when discussing climate change with students?
- **Evaluate:**  
Question: Is population growth a driver of climate change?

**3:15 Break**

**3:30 Discussion: Future Climate Change**

- Climate change denial/skepticism
- Alternative energies
- Climate change hiatus
- Global warming - more than just rise in surface temperature
- Challenges of teaching future climate change in the classroom

**4:20 Course Evaluation**

**4:30 Adjourn**