Weather and Climate: Detailed Outline

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?*
    - 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?
- Explain: Atmospheric Greenhouse Effect
    - Quick calculations:
- Kinesthetic Activity: *Long and Short of It.*

11:50 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_2 and H_2O) 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_2 in the model?
- Discussion: Why is Arrhenius's number off for doubling of CO_2?

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**

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

4:00 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).

4:25 How to find Little Shop of Physics

4:30 Adjourn

Evening

5:30 - 6:30 Little Shop of Physics (at Physics Building on CSU main campus)

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: 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
- Engage: Bubbles in aquarium of CO_2
- 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 Evaluate: If they air outside an airplane in flight is cold, why do they need to use air conditioning on the airplane?

10:00 Break

10:15 Engage: Radio Sond

10:30 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)
- Engage: *Be the Parcel*
- Explain: Moist adiabatic lapse rate

11:10 Extend, Explain: Thunderstorms, Supercells, Tornados

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

11:40 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?

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 Liquid Nitrogen Ice Cream

1:10 Question Time: Get to know the presenters, participant questions.

1:20 Science in History: Discovery of the Stratosphere

- Interactive evaluation of sounding data

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: "Hammer Time"
- 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)
- Engage/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 Time allowing: Surface force balance

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

4:15 Clouds in a Glass of Beer

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 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

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
- Explore: Spreadsheets and Chaos
- 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?

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 **Evaluate: 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