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High School Climate Science Curriculum
Course learning goals

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Current Climate

1. Earth climate is determined by a balance between absorbed sunlight and emitted infrared radiation. Because the earth rotates daily on an axis that is tilted relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on diffrent parts of the earth during the year. The difference in intensity of sunlight produces the seasonal variations in temperature.

   Describe the difference between climate and weather.
   (Didn't find in Kump) Addressed in http://eo.ucar.edu/educators/ClimateDiscovery/LIA_lesson1_9.28.05.pdf students collect and graph local weather data, learn distinctions between weather and climate and understand that daily weather measurements are highly variable compared to long-term climate data.
   And could be followed up with Purkey Lab 1

   Given the emissivity of the atmosphere and the albedo of a planet, determine the radiative equilibrium temperature. Explain why the atmospheric temperature (radiation temperature of the planet) is different from the surface temperature.
   (term emissivity not used in Kump; Ch. 3)

   Explain what causes the seasons. (Ch. 4)
   Explain how the earth's tilt causes the seasons.

2. Sunlight warms the tropics more than the polar latitudes, producing a temperature difference. The ocean and atmosphere move heat polewards to help warm the polar latitudes. In addition, the warmer tropical atmosphere holds more water vapor than the rest of the atmosphere. Evaporation from the tropical ocean cools the tropics and condensation warms the atmosphere elsewhere.

   Plot the (zonal mean) solar radiation absorbed at the earth surface as a function of latitude from the south pole to the north pole. On the same plot, plot the distribution of longwave (infrared) radiation emitted to space.. Using arrows, show the direction of heat transport in the atmosphere and oceans in each hemisphere. (Ch. 3 and 4)
   Zonal mean might not be a familiar term.

3. Regional climate results from variations in latitude and altitude, and from the position of mountain ranges, oceans, and lakes. Dynamic processes such as heat and moisture transport between earth's surface and atmosphere, heat transport in the ocean and atmosphere, and cloud formation influence climate as well.

   Describe why sea breeze occurs and the importance of land-sea contrast.
   Describe why the monsoons occur in the context of land-sea contrast.
   (Ch. 4)

4. Greenhouse gases in the atmosphere, such as carbon dioxide and water vapor, are transparent to most of the incoming sunlight but not to the infrared radiation emitted by the warm surface of the earth, which is then absorbed in the atmosphere. This absorbed energy warms the atmosphere, which in turn warms the earth's surface by emission of infrared radiation.

   Describe why anthropogenic carbon dioxide is an important greenhouse gas
   Describe what factors determine how potent a greenhouse gases is
      Absorption spectrum
      Concentration
      The strength of absorption per unit mass
      The structure of the molecules that leads to more absorption
   (Kump Ch. 3)

   Describe the vertical distribution of heating and cooling owing to greenhouse gases (heating at the surface and cooling at high altitudes).
   Kump Ch. 4
   Terrarium Demonstration
   Hadley Cell Lab (NASA MERRA data)

5. Natural factors, including volcanic activity, cause climate changes over human time scales (tens or hundreds of years). El Nino, a warming of the eastern equatorial Pacific Ocean with large changes in the tropical atmosphere, happens every 2 to 7 years. There are impacts of El Nino throughout the globe with some regions becoming warmer or wetter and others becoming colder and drier.

   Describe the concepts of forcing (Kump Ch. 2), feedback (Kump Ch. 3) and climate sensitivity (on pg. 52 of Kump, bu not called sensitivity, so this would need to be explained. A good topic for our next Summer PD).
   Determine whether coupling between processes in the earth system would be a negative (damping) or positive (amplification) feedback.
   e.g. atms H20 and greenhouse effect? Snow/ice extent, albedo and temperature?

   Feebacks and coupling handled in ch. 2, ch. 3, 6, 14, 19,
   Thompson Climate Model in Excel

Past Climate

6. Climate changes over many millions of years are dominated by changing atmospheric composition, the changing configuration of continents, and the erosion rates of mountains. Climate variations over many thousands of years, like the Ice Ages, are driven primarily by changes in Earth's orbit around the Sun and the tilt of Earth's axis of rotation. Ice age climate impacts can be seen in Pacific Northwest landscape.

   Describe the time scales of orbital change and how small changes in solar insolation can lead to dramatic climate changes. (Ch. 4, 14)

   Determine the rates of change of temperature for past climate changes. (Need data to play with, on different time scales-Ashley's ice core lab?)

   Explain the difference between stable and radioactive isotopes.

   Describe how radioactive isotopes are used to determine age. (Ch. 5, 12, 14)

   Describe how oxygen isotopes and other proxy records (e.g. tree rings) can be used to determine the climate of the past. (Ch. 14, 15)

   Describe the relationship between carbon dioxide and temperature over the ice ages both in words and graphically. (Ch. 1)

7. On long (geologic) time scales, carbon is cycled between the ocean, atmosphere, and lithosphere (rocks). Feedback between atmospheric temperature and carbon dioxide concentrations amplify variations in ice age climates.

   Describe the sources and sinks for carbon in the atmosphere, ocean, and lithosphere. Given the fluxes between the reservoirs and the size of the reservoirs, determine the residence time of carbon in each reservoir.

   (Kump Ch. 8 and 15) Ashley's Ice Core Activity

Future Climate

8. Over the last 5000 years (the Holocene), carbon concentration in the atmosphere has been constant until the industrial revolution when human activity began increasing carbon in the atmosphere and in the upper ocean. When greenhouse gas concentrations increase in the atmosphere, more thermal energy is absorbed, further warming the earth's surface. There are feedbacks in the climate system that can amplify the warming.

   Describe how the emissivity (w/c) of the atmosphere depends on the concentration of carbon dioxide in the atmosphere.

Given a change in the emissivity (w/c) of the planet owing to an increase in carbon dioxide, and given the feedbacks, calculate the change in surface temperature of the planet using a one-layer atmosphere model. (Ch. 3)

9. Multiple lines of observational evidence show that the earth has warmed over the last century. Observations include increases in earth's surface temperature, warming of the upper km of the ocean, retreat of mountain glaciers, sea level rise and Arctic sea-ice retreat. Other evidence can be found in local changes in the number of frost free days, and changes in the timing of the life cycle of plants and animals (phenology).

Given a series of graphical representations, describe how multiple lines of evidence show that the climate system warmed in the 20th century.
(Purkey Lab 2 Local and Global Temp Trends)
IPCC
Ch. 15

10. Climate models show that the observed warming can only be explained by the increase of greenhouse gases in the atmosphere. The magnitude of warming of the earth's surface over this century is expected to be 2 to 10 C. The strength of the warming depends on how much greenhouse gases are trapped in the atmosphere and the strength of the feedbacks in the climate system. (Ch. 15; IPCC)

Describe the different anthropogenic influences on radiative forcing of the planet at present and why each of the factors is important.

Determine the factors that will control the rise in temperature over the next century and what physics will control those factors including:

Greenhouse gas concentration
Feedbacks (ice, clouds, land cover, water vapor, lapse rate, ocean heat uptake)
Aerosols

Discuss how the future forcing and feedbacks are predicted and the uncertainty associated with that prediction.

Be able to use a distribution of predicted change to determine the mean and range of the predictions. (Is this in Sarah's lab?)

Discuss the rate of change of the climate in the 20th and 21st century and compare that against climate change in the geological record.

Describe how climate models are used to attribute climate change of the 20th century to anthropogenic forcing, and how climate models are used to predict future climate.

11. Climate models show that warming is predicted everywhere on the globe by the end of this century. The models also show that the high latitudes and tropics will have a

tendency to get wetter, while the subtropics will get dryer. Throughout the globe, when it does rain, these events will be more intense. Impacts of climate change will depend on the region.

Use a graphical representation of the Clausius-Clapeyron relation, determine how much the saturation vapor pressure will increase for a degree C temperature rise. Link that to changes in the hydrological cycle and rain. (Chapter 4, but relationship not defined as Clausius-Clapeyron—perhaps something to explore in teacher PD)

Discuss the level of certainty for predictions of different parts of the climate system in the 21st century. (Chapter 15)

12. Of the current emissions of carbon dioxide, one half is trapped in the atmosphere,¼ absorbed by the oceans, and ¼ by the terrestrial biosphere (plants).

Determine the residence time of carbon dioxide in the surface ocean, the deep ocean, the ocean sediments, and the terrestrial biosphere and soils.
(Ch. 8)

13. As carbon dioxide levels in the atmosphere rise, ocean water becomes more acidic, threatening the survival of shell-building marine species and the food webs of which they are a part. (Ch. 14 and 16)

Describe what organisms will be most susceptible to the impacts of ocean acidification
Describe what regions will see the effects of ocean acidification first.

14. The current excess heat in the climate system is predominantly stored in the ocean. If the concentration of greenhouse gases were kept at today's levels, the climate system would still warm another degree C owing primarily to the heat capacity of the ocean (climate change commitment).

Calculate the differences in the heat capacity of the atmosphere and ocean.
(Ch.4, but more information will be needed)

Tools

A. Math: solving problems, analyzing data and making logical arguments. Specific objectives: unit conversions, scientific notation, linear equations, rates and slopes, algebraic solutions, modeling, conservation relationships.

B. Graphical analyses: Understand (i) graphical representation of data, including time series, correlation plots; (ii) spatial map data.

C. Software: develop familiarity with excel and other web based tools for quantitative analysis.

Orphaned topics

Mass budgets
Residence time of water and carbon