RLP-ESB · RLP Earth Science B — Water, Climate, Resources and Hazards

Unit 3: Climate Change: Evidence and Models

Practice Workbook. The same problems, in the same order, as the Practice sections of the online lessons.

Name _____ Period _____

Lesson 3.1 — The Keeling Curve and a Warming World

FLUENCY

1. Use technology to find the least-squares line and the correlation coefficient for (1, 10), (2, 13), (10, 33), (12, 35), (13, 39).

2. Mauna Loa CO_2 was 369.71 ppm in 2000 and 390.10 ppm in 2010. What was the average rate?

3. It was 390.10 ppm in 2010 and 414.21 ppm in 2020. What was the average rate?

4. By what percentage is 424.61 ppm (2024) above the pre-industrial 280 ppm?

APPLICATION

5. NASA GISTEMP anomalies (relative to 1951-1980) were −0.02 °C in 1960, 0.26 in 1980, 0.39 in 2000 and 1.01 in 2020. Compute the change per decade for 1960-1980 and 2000-2020.

6. The 1880-1899 mean anomaly was about −0.22 °C and 2024 was 1.28 °C. How much warmer was 2024 than the late 1800s?

7. At 1 ppm = 2.13 GtC, how many gigatons of carbon did the atmosphere gain from 2014 (398.81 ppm) to 2024 (424.61 ppm)?

CHALLENGE

8. A least-squares line through 1975-2024 GISTEMP rises about 0.20 °C per decade and gives an anomaly of about 1.54 °C in 2050. Explain why this straight-line forecast could be too low or too high, giving one reason each way.

REVIEW

9. Review (Unit 2): find the CO_2 forcing at 400 ppm using 5.35 ln(C/280).

Lesson 3.2 — Carbon Dioxide Meets the Ocean

FLUENCY

1. How many gigatons of carbon are in the atmosphere at 424.61 ppm (1 ppm = 2.13 GtC)?

2. The atmosphere gains 2.4 ppm in a year. How many GtC is that?

3. Ocean pH falls from 8.2 to 8.1. By what factor does the hydrogen-ion concentration increase?

APPLICATION

4. Emissions are 11 GtC per year and the atmosphere gains 2.58 ppm per year. What is the airborne fraction, and where does the rest go?

5. In the lab a 5.20 g shell piece in seltzer dried to 4.94 g after 24 hours, and one in tap water went from 5.10 g to 5.08 g. Find each percent mass lost and explain the difference.

6. Explain the feedback between ocean temperature and ocean carbon uptake, and say whether it is reinforcing or balancing.

CHALLENGE

7. The ocean takes up about a quarter of 11 GtC per year. What fraction of the ocean's roughly 38,000 GtC reservoir is that each year? Why can this small fraction still change surface-ocean chemistry noticeably?

REVIEW

8. Review (Unit 2): find the no-greenhouse temperature of a planet absorbing 200 W/m^2.

Lesson 3.3 — How Do We Know? Fingerprints and a Rising Sea

FLUENCY

1. Use technology to find the least-squares line and the correlation coefficient for (4, -1), (5, -2), (8, -7), (9, -7), (11, -13), (13, -10).

2. Sea level at Pensacola rose about 2.73 mm per year from 1923 to 2025. How much is that per century, in cm?

3. At 6.54 mm per year (the 1993-2025 Pensacola rate), how much would the sea rise from 2025 to 2050?

4. At the IPCC's 2006-2018 global rate of 3.7 mm per year, how much would the sea rise in 25 years?

APPLICATION

5. In the ice lab, cup A (ice on clay 'land') rose 4 mm after melting and cup B (floating ice) rose 0 mm. Explain both results and name a real example of each kind of ice.

6. Give two independent lines of evidence that the added CO_2 comes mainly from fossil fuels.

7. Global sea level rose about 0.20 m from 1901 to 2018. What average rate is that, and how does it compare with the 2006-2018 rate of 3.7 mm/yr?

CHALLENGE

8. The top 700 m of the ocean warms by 0.5 °C. Seawater expands by about 0.0002 of its volume per °C (an approximate value). How much would sea level rise from thermal expansion alone?

REVIEW

9. Review (Unit 2): 3,000 J warms 0.250 kg of water by how much?

Lesson 3.4 — Climate Models and Human Choices

FLUENCY

1. A quantity starts at 8,000 and grows by 4% each year. Write a model and find its value after 4 years, to the nearest whole number.

2. In the three-line model, emissions of 9 GtC per year with an airborne fraction of 0.45 raise CO_2 by how much per year?

3. Find the CO_2-only warming, $1.8 \times \ln(C/280) / \ln 2$, at 500 ppm.

4. Find the forcing at 485 ppm.

APPLICATION

5. Run the three-line model from 427.35 ppm (2025) to 2050 with constant emissions of 11 GtC per year and airborne fraction 0.45. Find C, the forcing and the CO_2-only warming in 2050.

6. Repeat with emissions falling steadily to half (5.5 GtC) by 2050. How much lower is CO_2 in 2050 than with constant emissions?

7. The IPCC's best estimates for 2081-2100 are 1.8 °C (SSP1-2.6), 2.7 °C (SSP2-4.5) and 4.4 °C (SSP5-8.5). What is the difference between the lowest and highest, and what sets it?

CHALLENGE

8. A warming ocean absorbs less, raising the airborne fraction from 0.45 to 0.55. With constant 11 GtC emissions, what is C in 2050, and how does this change compare with halving emissions?

REVIEW

9. Review (Unit 1): a basin holds 900,000 acre-feet with recharge 250,000 and pumping 310,000 per year. How much remains after 5 years?

Unit 3 checkpoint

1. Mauna Loa CO_2 rose from 398.81 ppm (2014) to 424.61 ppm (2024). What was the average rate?
   A. 0.86 ppm/yr
   B. 1.6 ppm/yr
   C. 2.58 ppm/yr
   D. 25.8 ppm/yr
2. True or false: The yearly wiggle in the Keeling curve is caused by Northern Hemisphere plants.
3. 1 ppm of atmospheric CO_2 contains about _____ GtC.
4. About what share of recent CO_2 emissions has stayed in the atmosphere?
   A. About 10%
   B. About 50%
   C. About 90%
   D. All of it
5. What happens to ocean pH as seawater absorbs CO_2?
   A. It rises
   B. It falls
   C. It stays the same
   D. It becomes neutral
6. True or false: Melting floating sea ice is a major direct cause of sea-level rise.

7. At 2.0 mm/yr, sea level rises about _____ cm per century.

8. Which is evidence that recent CO_2 comes from fossil fuels?
   A. CO_2 is colorless
   B. The carbon-13 fraction of atmospheric CO_2 is falling
   C. Volcanoes erupt
   D. Trees grow in summer

9. In the three-line model, what does the airborne fraction represent?
   A. The share of emissions that stays in the air
   B. The share of sunlight reflected
   C. The share of heat stored in the ocean
   D. The share of CO_2 from volcanoes

10. True or false: Models run with only natural drivers reproduce the warming since the mid-1900s.

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