

# Mr. Brown's Science Labs

## *Earth & Space Science Regents Review*

*Climate, Climate Change, Human Impact, Air Masses & Fronts, Wind & Pressure, Weather Maps, and Natural Disasters*

<b>Question Set:</b>	5 Clusters · 5 Questions Each · 25 Total
<b>Aligned To:</b>	NYS Earth & Space Science Regents (Jan 2026 question formats)
<b>Format Mimics:</b>	Jan 2026 Regents Q1, Q2, Q6, Q9, Q14, Q16, Q19, Q22
<b>Reference:</b>	2024 Edition NYS Earth & Space Science Reference Tables (ESRT)
<b>Scoring:</b>	1 point per question · Total: 25 points · Final grade calculated
<b>Student Name:</b>	
<b>Class Period:</b>	
<b>Date:</b>	

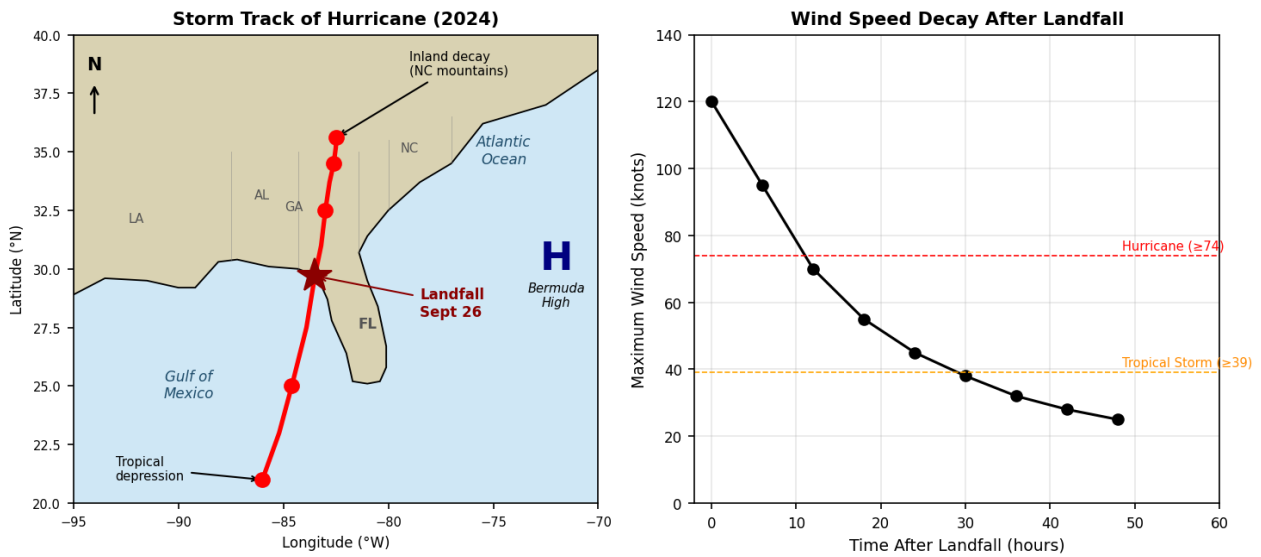
**Directions:** Use your knowledge of Earth and Space Sciences and the 2024 Edition Reference Tables for Earth and Space Sciences to answer all questions. Each question is worth 1 point. Some questions ask you to place an X or check mark in a box; others ask you to choose the best multiple-choice answer (1, 2, 3, or 4); some are short constructed-response items requiring justification. The official Regents reference tables can be downloaded at: [nysed.gov/state-assessment/earth-space-science-reference-tables](https://nysed.gov/state-assessment/earth-space-science-reference-tables).

*Searchable tags: NYS Regents Earth Space Science, Regents review, climate change, human impact, hurricanes, tornadoes, weather map, air mass, cold front, warm front, Bermuda High, Nor'easter, urban heat island, Arctic sea ice, albedo, greenhouse gases, Mr. Brown's Science Labs.*

# Cluster 1 | Tracking a 2024 Hurricane: Steering Winds, Air Masses, & Inland Flooding

Base your answers to questions 1 through 5 on the information below and on your knowledge of Earth and Space Sciences. Some questions may require the use of the 2024 Edition Reference Tables for Earth and Space Sciences.

In late September 2024, a powerful hurricane rapidly intensified over the warm waters of the Gulf of Mexico, where sea-surface temperatures reached nearly 30°C — well above the 26°C threshold typically required for tropical-cyclone development. The storm made landfall along Florida's Big Bend as a major hurricane with sustained winds over 120 knots and a minimum central pressure below 950 mb. After landfall, the system tracked rapidly northward, steered by winds along the western edge of the **Bermuda High** — a semi-permanent high-pressure system that sits over the subtropical North Atlantic. The storm dropped historic rainfall over the southern Appalachian Mountains, where orographic lifting wrung enormous amounts of water vapor from the warm, moist tropical air mass. Climate scientists noted that the warmer-than-average ocean and atmosphere likely supplied additional energy and moisture to the storm — a pattern increasingly tied to long-term climate change.



Storm track of the 2024 hurricane and graph of maximum wind speed after landfall.

1 Complete each of the three statements below by placing an **X** in the box that correctly identifies how atmospheric and oceanic conditions supported the formation and tracking of the 2024 hurricane. [1]

**Statement 1:** Hurricanes are able to rapidly intensify when they form over

<input type="checkbox"/>	ocean water at least 26 °C, allowing rapid evaporation
<input type="checkbox"/>	ocean water below 18 °C, slowing evaporation

**Statement 2:** At the center of the storm shown on the storm-track map, the air pressure is

<input type="checkbox"/>	very low pressure that produces inward-spiraling winds
<input type="checkbox"/>	very high pressure that produces outward-flowing winds

**Statement 3:** After landfall, the steering flow that carried the storm into the Appalachians was provided by

<input type="checkbox"/>	the clockwise circulation around the Bermuda High pulling the storm northward
<input type="checkbox"/>	the counterclockwise circulation around the Bermuda High pulling the storm southward

2 Several statements about hurricanes and the conditions in 2024 are listed below.

**Statements:**

**Statement 1:** Hurricanes typically lose energy rapidly after moving over land because their warm-water energy source is cut off.

**Statement 2:** Hurricanes intensify most readily when sea-surface temperatures are below 18 °C.

**Statement 3:** Steering winds along the southern and western edge of the Bermuda High push tropical systems poleward (northward).

**Statement 4:** Hurricanes always rotate clockwise in the Northern Hemisphere because of the Coriolis effect.

**Statement 5:** Warmer ocean and atmosphere temperatures associated with climate change can supply additional water vapor and energy to a storm.

**Statement 6:** Inland flooding from a hurricane is reduced when warm, moist air is forced upward over mountains.

**Which combination of statements correctly summarizes the 2024 hurricane's behavior and the role of the Bermuda High?**

- (1) Statements 1, 3, and 5
- (2) Statements 2, 4, and 6
- (3) Statements 1, 4, and 5
- (4) Statements 3, 4, and 6

3 A student claims that climate change increased the destructive potential of the 2024 hurricane. Which statement provides the **most correct evidence** from the passage to support this claim?

- (1) Cooler-than-average Gulf temperatures provided more energy to the storm before landfall.
- (2) Warmer-than-average sea-surface temperatures and atmospheric water vapor supplied additional energy and moisture to the storm.
- (3) Stronger trade winds in 2024 caused the storm to weaken before reaching Florida.
- (4) Decreased rainfall over the Appalachians prevented widespread inland flooding.

4 A student makes the following claim:

*The hurricane's maximum sustained wind speed dropped below tropical-storm strength (39 knots) within 24 hours of landfall.*

<input type="checkbox"/>	<b>Support</b>
<input type="checkbox"/>	<b>Refute</b>

**Justify your response using evidence from the wind-speed graph:**

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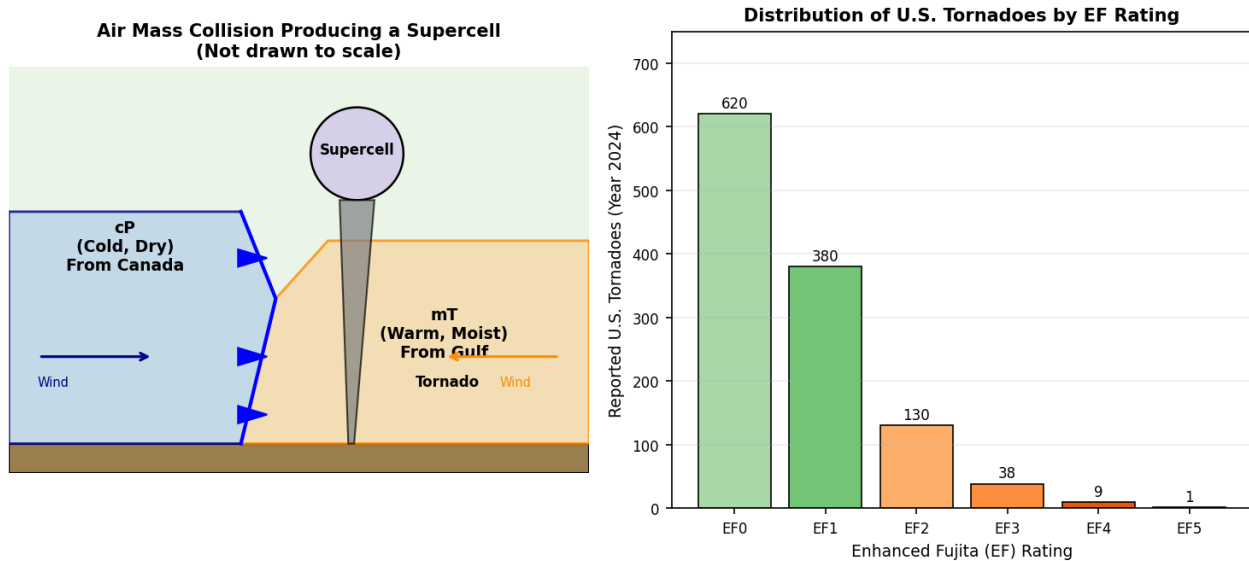
5 The rapid weakening of the storm's maximum wind speed during the 48 hours after landfall is best explained by

- (1) increased friction with the land surface combined with the loss of warm-ocean evaporation
- (2) a strengthening Bermuda High that pumped energy into the storm
- (3) an increase in the Coriolis effect at higher latitudes
- (4) the eyewall replacement cycle adding additional warm-water heat to the storm

## Cluster 2 | Tornado Outbreak: Air Masses Collide Over the Plains

Base your answers to questions 6 through 10 on the information below and on your knowledge of Earth and Space Sciences.

On a humid spring afternoon over the U.S. Great Plains, a sharp boundary developed between two very different air masses. To the north and west, a continental polar (cP) air mass had pushed south out of central Canada — cool and dry, with surface temperatures near 13 °C. To the south, a maritime tropical (mT) air mass surged north out of the Gulf of Mexico, carrying surface dewpoints in the low 20s °C. As the dense cP air wedged beneath the lighter mT air along the cold front, the warm, moist air was forced upward thousands of meters. As it rose, the water vapor in it condensed, releasing latent heat and powering massive cumulonimbus storms with anvil-shaped tops. Inside the strongest storms — known as **supercells** — a rotating column of air called a **mesocyclone** developed. From several of these mesocyclones, narrow funnel clouds descended to the ground as tornadoes. The 2024 U.S. tornado season produced over 1,150 confirmed tornadoes, the great majority of which were rated EF0 or EF1 on the Enhanced Fujita scale.



Air mass collision producing a supercell, and the distribution of U.S. tornadoes by EF rating in 2024.

6 Complete each of the three statements below by placing an **X** in the box that correctly describes the air-mass interaction that produced the supercell. [1]

**Statement 1:** The cP air mass shown in the model is best described as

- |                          |   |
|--------------------------|---|
| <input type="checkbox"/> | cold and dry, having formed over interior Canada      |
| <input type="checkbox"/> | warm and humid, having formed over the Gulf of Mexico |

**Statement 2:** At the boundary between the two air masses, the colder, denser cP air is

- |                          |   |
|--------------------------|---|
| <input type="checkbox"/> | rising over the warmer air mass and cooling slowly                |
| <input type="checkbox"/> | wedging beneath the warmer air mass and forcing it rapidly upward |

**Statement 3:** As the warm, moist mT air is forced upward, the water vapor in it will

- |                          |  |
|--------------------------|--|
| <input type="checkbox"/> | condense and release latent heat, powering the storm |
| <input type="checkbox"/> | evaporate and absorb heat, weakening the storm       |

7 A weather observer in Oklahoma recorded the following observations as a severe thunderstorm approached.

**Observations:**

- A. Barometric pressure fell rapidly over the past hour.
- B. Surface winds at the station were calm with no shift in direction.
- C. Towering cumulonimbus clouds with anvil-shaped tops were visible to the west.
- D. Surface temperature rose steadily under clear skies.
- E. Large hail and a wall cloud were reported just before the funnel was sighted.
- F. High cirrus clouds were the only visible cloud cover overhead.

**Which set of observations correctly identifies evidence of a developing supercell capable of producing a tornado?**

- (1) Observations B, D, and F
- (2) Observations A, C, and E
- (3) Observations B, C, and F
- (4) Observations A, D, and F

8 Write the correct letter from the choices below on the line at the end of each sentence to complete each statement about tornado formation. [1]

**Choices for Statement 1:**

- A — converging at the surface and rising rapidly aloft
- B — diverging at the surface and sinking rapidly aloft

**Choices for Statement 2:**

- C — counterclockwise
- D — clockwise

**Choices for Statement 3:**

- E — observed damage to structures and vegetation
- F — the central pressure of the rotating column

**Statement 1:** When a tornado is forming, surface winds in the region of the mesocyclone are typically \_\_\_\_\_

**Statement 2:** In the Northern Hemisphere, the rotating column of air inside a supercell-spawned tornado spins \_\_\_\_\_

**Statement 3:** The Enhanced Fujita (EF) scale rates tornado intensity primarily based on \_\_\_\_\_

9 The events listed below describe the formation of a tornado from an approaching supercell thunderstorm. Place the events in the correct temporal sequence in the graphic organizer below, and justify the sequence using one atmospheric process. [1]

**Events to place in order:**

- Warm, moist mT air is forced rapidly upward along the cold front.
- A funnel cloud descends from the storm base and reaches the ground as a tornado.
- A maritime tropical (mT) air mass meets a continental polar (cP) air mass along a cold front.
- A rotating mesocyclone develops within the supercell as winds at different altitudes blow in different directions (wind shear).
- A towering cumulonimbus cloud with an anvil top forms.

<b>Oldest / First →</b>
<b>Youngest / Last →</b>

**Justification:**

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10 Based on the bar chart of 2024 U.S. tornadoes, which statement is most accurate?

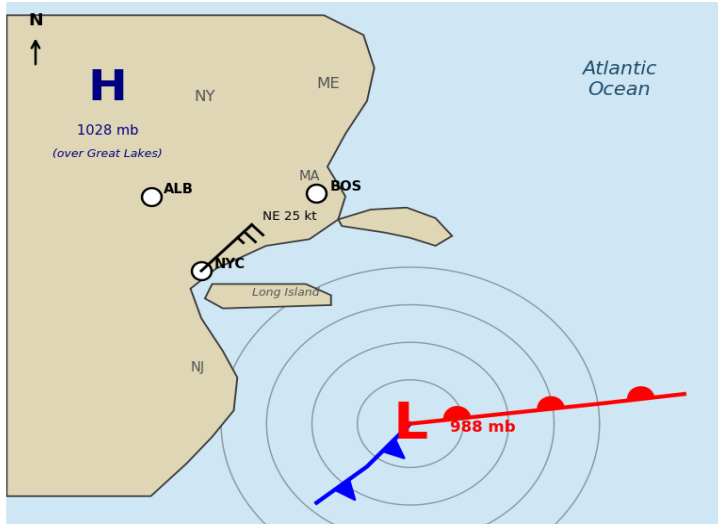
- (1) Most reported tornadoes in 2024 were rated EF4 or EF5.
- (2) Tornadoes weaker than EF2 made up the great majority of reported tornadoes.
- (3) Roughly equal numbers of EF1 and EF4 tornadoes were reported.
- (4) EF5 tornadoes were the most common rating reported.

## Cluster 3 | Reading the Weather Map: A Nor'easter Strikes the Northeast

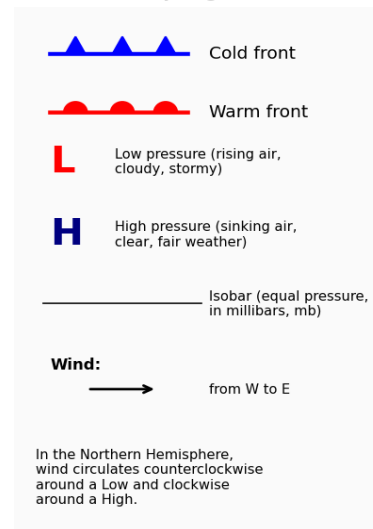
Base your answers to questions 11 through 15 on the information below and on your knowledge of Earth and Space Sciences.

A **nor'easter** is a powerful low-pressure system that develops along the East Coast of North America, typically in the cooler months. It draws its energy from the sharp temperature contrast between cold continental air over land and the relatively warm waters of the Gulf Stream offshore. On the surface weather map below, a deep low-pressure center (988 mb) is positioned just off the coast of New Jersey, while a strong high-pressure system (1028 mb) is centered over the Great Lakes region. Closely spaced isobars around the low indicate a strong pressure gradient and powerful winds. A cold front extends to the southwest from the low and a warm front extends to the east. Stations along the coast — including New York City and Boston — are reporting strong onshore winds from the northeast, heavy precipitation, and rapidly falling barometric pressure. Cities far inland near the high pressure center experience clear, cold, and calm conditions.

Surface Weather Map — Nor'easter Approaching the U.S. Northeast



Map Legend



Surface weather map of an approaching nor'easter, with map legend.

**11** Complete each of the three statements below by placing an **X** in the box that correctly interprets the surface weather map. [1]

**Statement 1:** The closely spaced isobars near the low pressure center indicate

<input type="checkbox"/>	strong, fast winds caused by a steep pressure gradient
<input type="checkbox"/>	light, calm winds caused by a weak pressure gradient

**Statement 2:** At the high pressure (H) center over the Great Lakes, air motion most likely produces

<input type="checkbox"/>	rising air, clouds, and precipitation
<input type="checkbox"/>	sinking air, clear skies, and fair weather

**Statement 3:** A station located between the warm front and the cold front is most likely experiencing

<input type="checkbox"/>	rising temperature, increasing humidity, and possible thunderstorms
<input type="checkbox"/>	rapidly falling temperature, decreasing humidity, and clearing skies

**12** A student claims that New York City will receive heavy precipitation and very strong winds during this storm. Which statement provides the **most correct evidence** from the map to support this claim?

- (1) NYC's distance from the high-pressure center over the Great Lakes is greater than from the low.
- (2) The closely spaced isobars surrounding the low and the strong onshore winds blowing off the warm Atlantic Ocean.
- (3) The Atlantic Ocean is shown to the east of NYC on the map.
- (4) Boston is positioned slightly farther north of the low than NYC is.

**13** Which row in the table below correctly identifies the surface wind direction at NYC and the most likely sky condition during the height of the storm?

Row	Wind Direction at NYC	Sky Condition
(1)	from the southwest	scattered clouds, light rain
(2)	from the northeast	overcast skies with heavy precipitation
(3)	from the north	clear skies, no precipitation
(4)	from the south	dense fog, no precipitation

**14** A student makes the following claim:

*The low-pressure system shown on the map will most likely move out to sea (eastward) and have very little impact on coastal cities like New York City and Boston.*

<input type="checkbox"/> <b>Support</b>
<input type="checkbox"/> <b>Refute</b>

**Justify your response using evidence from the map and prevailing wind directions:**

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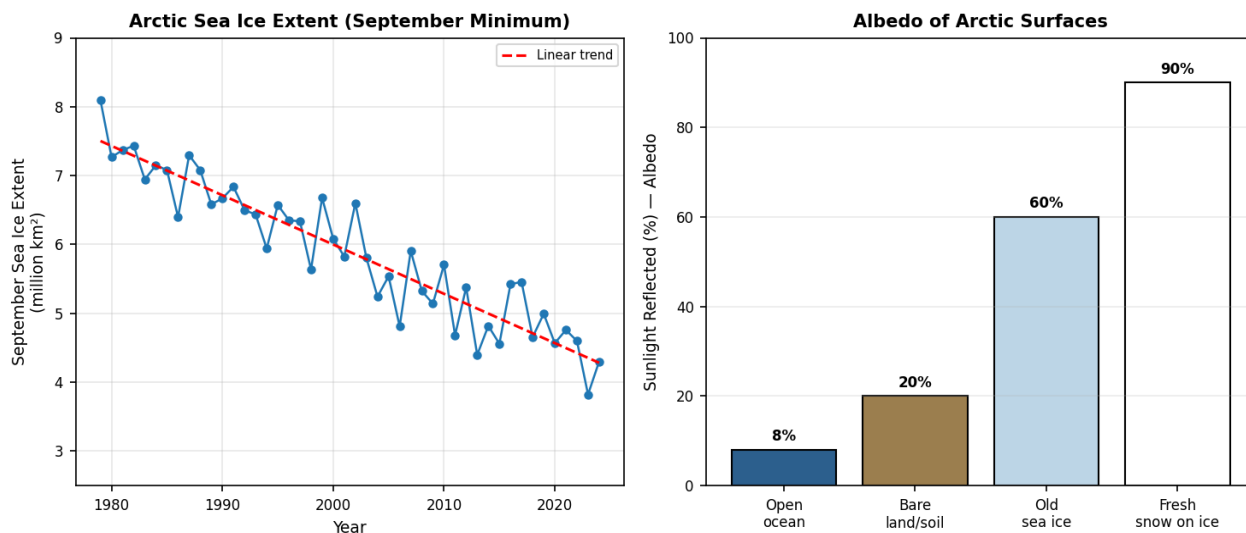
**15** As the cold front shown on the map sweeps through New York City, which sequence of weather changes is most likely to occur at the surface?

- (1) rising temperature, then thunderstorms, then dense fog
- (2) showers and thunderstorms, then dropping temperature, then clearing skies and gusty winds from the northwest
- (3) clearing skies, then warm temperatures, then steady rain
- (4) warm sunny weather, then sudden snow, then no change in pressure

## Cluster 4 | The Vanishing Arctic: Climate Change in the Polar North

Base your answers to questions 16 through 20 on the information below and on your knowledge of Earth and Space Sciences.

Since satellite measurements began in 1979, the extent of Arctic sea ice at its September minimum has decreased dramatically — from roughly 7.5 million km<sup>2</sup> to about 4.3 million km<sup>2</sup> in 2024. The loss of sea ice changes the **albedo** of Earth's surface in the Arctic. Bright white ice and snow reflect 60–90% of the Sun's incoming radiation, while open ocean water reflects only 5–10%. As ice retreats, more dark ocean is exposed, more solar energy is absorbed, the ocean warms further, and even more ice melts — a **positive feedback loop**. The Arctic is now warming roughly four times faster than the global average. This warming has been linked to changes in the high-altitude **polar jet stream** and disruptions of the polar vortex, which can push exceptionally cold air far south into the United States and produce extreme winter weather in states like New York. Atmospheric carbon dioxide measured at Mauna Loa, Hawaii has risen from approximately 315 ppm in 1960 to over 422 ppm in 2024, and is the primary driver of long-term warming.



Arctic sea ice extent (September minimum) since 1979 and albedo of common Arctic surfaces.

16 A polar climate scientist recorded the following observations during fieldwork in 2024.

### Observations:

- A. The September Arctic sea ice extent was about 4.3 million km<sup>2</sup>, the lowest in decades.
- B. Atmospheric CO<sub>2</sub> concentration at Mauna Loa was over 422 ppm in 2024.
- C. Open ocean water reflects only about 8% of incoming sunlight.
- D. Open water absorbs more solar energy than sea ice, warming the surrounding sea.
- E. The Manhattan subway ridership decreased between 2020 and 2024.
- F. A warmer Arctic Ocean delays autumn freeze-up, exposing more dark water for longer.

Which set of observations correctly identifies evidence for the ice-albedo positive feedback loop?

- (1) Observations A, C, and D
- (2) Observations A, D, and F
- (3) Observations B, C, and E
- (4) Observations B, E, and F

17 Write the correct letter from the choices below on the line at the end of each sentence to complete each statement about Arctic climate change. [1]

**Choices for Statement 1:**

- A — decrease, because more dark ocean is exposed
- B — increase, because more bright ice is exposed

**Choices for Statement 2:**

- C — absorbed by Earth's surface
- D — reflected back into space

**Choices for Statement 3:**

- E — accelerates the rate of global warming
- F — slows the rate of global warming

**Statement 1:** As Arctic sea ice continues to melt, the average albedo of Earth's polar regions will \_\_\_\_\_

**Statement 2:** With less ice and more open ocean, more solar energy will be \_\_\_\_\_

**Statement 3:** This change in surface albedo represents a positive feedback that \_\_\_\_\_

18 The events below describe the ice-albedo positive feedback loop. Place these events in the correct temporal sequence in the graphic organizer below, and justify your response. [1]

**Events to place in order:**

- Increased atmospheric CO<sub>2</sub> traps more outgoing infrared (long-wave) radiation.
- Average global temperature rises, including over the Arctic.
- Arctic sea ice melts, exposing dark open ocean.
- Less sunlight is reflected; more solar energy is absorbed by open water.
- The ocean and atmosphere warm even more, accelerating ice loss.

<b>Oldest / First →</b>
<b>Youngest / Last →</b>

**Justification:**

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**19** Several statements about Arctic climate change and its connection to mid-latitude weather are listed below.

**Statements:**

**Statement 1:** A weaker, more wavy polar jet stream can let cold Arctic air spill far south into the United States.

**Statement 2:** An increase in Arctic sea ice raises Earth's overall albedo, cooling the planet.

**Statement 3:** The Arctic is currently warming faster than the global average.

**Statement 4:** Atmospheric CO<sub>2</sub> at Mauna Loa has decreased steadily since 1960.

**Statement 5:** Disruptions to the polar vortex have been linked to extreme winter cold snaps in New York State.

**Statement 6:** Albedo of fresh snow on ice is lower than the albedo of open ocean water.

**Which combination of statements correctly describes the relationship between Arctic warming and mid-latitude weather?**

- (1) Statements 1, 3, and 5
- (2) Statements 2, 4, and 6
- (3) Statements 1, 4, and 6
- (4) Statements 3, 5, and 6

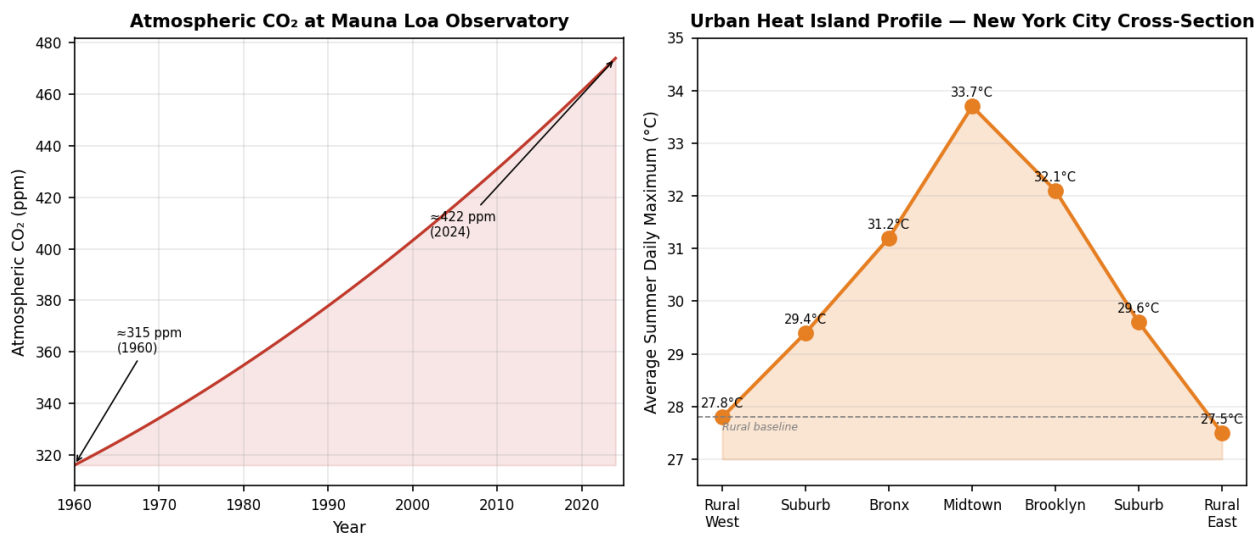
**20** Using the trend line on the Arctic Sea Ice Extent graph (a decline from approximately 7.5 million km<sup>2</sup> in 1979 to approximately 4.3 million km<sup>2</sup> in 2024), the approximate average rate of decline in September Arctic sea ice extent is closest to

- (1) 0.07 million km<sup>2</sup> per decade
- (2) 0.7 million km<sup>2</sup> per decade
- (3) 3.0 million km<sup>2</sup> per decade
- (4) 7.0 million km<sup>2</sup> per decade

## Cluster 5 | Cities & Climate: Urban Heat, Greenhouse Gases, & Human Impact

Base your answers to questions 21 through 25 on the information below and on your knowledge of Earth and Space Sciences.

On a hot summer afternoon in New York City, surface temperatures in dense neighborhoods like midtown Manhattan can be 5–7 °C warmer than in nearby rural areas of Long Island or the Hudson Valley. This temperature difference between cities and the surrounding countryside is known as the **urban heat island effect**. It happens because cities replace soil and vegetation with dark, low-albedo concrete and asphalt that absorb solar energy by day and re-radiate it as infrared heat. Buildings, vehicles, and air conditioning units add extra waste heat to the atmosphere. At the same time, atmospheric carbon dioxide measured at Mauna Loa Observatory has risen steadily from about 315 ppm in 1960 to over 422 ppm in 2024 — an increase tied directly to the burning of fossil fuels. Higher atmospheric CO<sub>2</sub> traps more of Earth's outgoing infrared radiation, raising global average temperatures. Mitigation strategies in NYC and other cities include planting more trees, installing reflective "cool roofs," using permeable pavements, and reducing fossil-fuel burning.



Atmospheric CO<sub>2</sub> at Mauna Loa Observatory and an urban heat island temperature profile across New York City.

**21** Complete each of the three statements below by placing an **X** in the box that correctly describes the urban heat island and greenhouse effects. [1]

**Statement 1:** Compared to surrounding rural areas, cities like New York City are typically

<input type="checkbox"/>	several degrees warmer than nearby rural areas
<input type="checkbox"/>	several degrees cooler than nearby rural areas

**Statement 2:** Concrete and asphalt have a lower albedo than grass and trees, so urban surfaces

<input type="checkbox"/>	absorb more incoming solar energy
<input type="checkbox"/>	reflect more incoming solar energy

**Statement 3:** Rising atmospheric CO<sub>2</sub> levels cause Earth's atmosphere to

<input type="checkbox"/>	trap more outgoing infrared (long-wave) radiation, warming the lower atmosphere
<input type="checkbox"/>	release more outgoing infrared radiation directly to space, cooling the lower atmosphere

**22** A student claims that human activities — especially the burning of fossil fuels — have caused atmospheric CO<sub>2</sub> to rise rapidly. Which statement, based on the Mauna Loa graph, provides the **most correct evidence** to support this claim?

- (1) Atmospheric CO<sub>2</sub> has remained constant at roughly 315 ppm since 1960.
- (2) Atmospheric CO<sub>2</sub> has decreased steadily since the Industrial Revolution.
- (3) Atmospheric CO<sub>2</sub> has risen from about 315 ppm in 1960 to over 422 ppm in 2024, paralleling decades of fossil-fuel use.
- (4) Atmospheric CO<sub>2</sub> varies only seasonally because of plant growth, not because of human activity.

**23** Based on the Urban Heat Island Profile graph for New York City, the approximate temperature difference between Midtown Manhattan and the surrounding rural areas is closest to

- (1) 1 °C
- (2) 6 °C
- (3) 12 °C
- (4) 0 °C

24 A student makes the following claim:

*Planting more street trees and replacing dark roofs with light-colored, reflective "cool roofs" in New York City will help reduce the urban heat island effect.*

<input type="checkbox"/>	<b>Support</b>
<input type="checkbox"/>	<b>Refute</b>

**Justify your response using the concept of albedo and evidence from the passage:**

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25 A NYC student records the following observations during a summer heat wave.

**Observations:**

- A. Air conditioners on every building exhaust large amounts of heat into the city air.
- B. Trees in Central Park lower local air temperatures by evapotranspiration.
- C. Atmospheric CO<sub>2</sub> at Mauna Loa has risen for over 60 years.
- D. Rural eastern Long Island reached 28 °C while Midtown reached 34 °C.
- E. Heavy car traffic adds waste heat and CO<sub>2</sub> to the local atmosphere.
- F. Light-colored cool roofs reflect more solar radiation than traditional dark roofs.

**Which set of observations correctly identifies *human-caused* factors that worsen the urban heat island effect?**

- (1) Observations A, B, and F
- (2) Observations B, C, and F
- (3) Observations A, D, and E
- (4) Observations C, D, and F

# Answer Key & Teacher Explanations

Score: 1 point per question · Total: 25 points · Final grade = (correct ÷ 25) × 100%

## Cluster 1 — 2024 Hurricane

1. **Statement 1:** ocean water at least 26 °C · **Statement 2:** very low pressure that produces inward-spiraling winds · **Statement 3:** the clockwise circulation around the Bermuda High pulling the storm northward.
2. (1) **Statements 1, 3, and 5.** Hurricanes lose energy over land (1), the Bermuda High steers tropical systems poleward (3), and warmer oceans/atmosphere supply more energy/moisture (5). Statements 2, 4, and 6 are factually incorrect.
3. (2) Warmer-than-average sea-surface temperatures and atmospheric water vapor supplied additional energy and moisture. The passage states SSTs near 30 °C — well above the 26 °C threshold.
4. **REFUTE.** The graph shows wind speeds at 24 hours after landfall were still about 45 knots — above the 39-knot tropical storm threshold. Wind speed did not drop below tropical-storm strength until between 24 and 30 hours after landfall.
5. (1) Increased friction with the land surface combined with the loss of warm-ocean evaporation. Hurricanes draw their energy from warm ocean water; cutting off that energy and adding land friction rapidly weakens them.

## Cluster 2 — Tornado / Air Mass Collision

6. **Statement 1:** cold and dry, having formed over interior Canada · **Statement 2:** wedging beneath the warmer air mass and forcing it rapidly upward · **Statement 3:** condense and release latent heat, powering the storm.
7. (2) **Observations A, C, and E.** Rapidly falling pressure (A), towering cumulonimbus with anvil tops (C), and large hail / wall cloud (E) are classic supercell signatures.
8. **Statement 1: A** (converging at the surface and rising rapidly aloft) · **Statement 2: C** (counterclockwise) · **Statement 3: E** (observed damage to structures and vegetation). The EF scale is a damage-based rating, not a direct wind-speed measurement.
9. **Correct sequence (oldest → youngest):**
- 1) mT and cP air masses meet along a cold front
  - 2) Warm, moist mT air is forced rapidly upward along the cold front
  - 3) A towering cumulonimbus cloud with an anvil top forms
  - 4) A rotating mesocyclone develops from wind shear within the supercell
  - 5) A funnel cloud descends from the storm base and reaches the ground as a tornado.
- Justification:** The sequence is driven by frontal lifting + condensation releasing latent heat + wind shear producing rotation.
10. (2) Tornadoes weaker than EF2 (i.e. EF0 + EF1 = 1,000 of about 1,178) make up the great majority.

## Cluster 3 — Reading the Weather Map: Nor'easter

11. **Statement 1:** strong, fast winds caused by a steep pressure gradient · **Statement 2:** sinking air, clear skies, and fair weather · **Statement 3:** rising temperature, increasing humidity, and possible thunderstorms (warm sector).
12. (2) Closely spaced isobars indicate a steep pressure gradient → strong winds, and the onshore wind direction (off the warm Atlantic) supplies moisture for heavy precipitation.
13. (2) Wind from the northeast (counterclockwise around the L just offshore), with overcast skies and heavy precipitation.
14. **REFUTE.** Counterclockwise circulation around the Low pulls strong onshore (NE) winds and Atlantic moisture directly into NYC and Boston, producing heavy precipitation, coastal flooding, and high winds — not a minor impact.
15. (2) Showers and thunderstorms during frontal passage, then dropping temperatures and clearing skies with gusty NW winds behind the cold front.

## Cluster 4 — The Vanishing Arctic

16. (2) **Observations A, D, and F.** A documents the ice loss, D states the energy-absorption consequence, F describes the delayed freeze-up that amplifies the loop. B and C are general facts that do not by themselves describe the feedback; E is irrelevant.
17. **Statement 1: A** (decrease, because more dark ocean is exposed) · **Statement 2: C** (absorbed by Earth's surface) · **Statement 3: E** (accelerates the rate of global warming).

**18. Correct sequence (first → last):**

- 1) Increased atmospheric CO<sub>2</sub> traps more outgoing infrared radiation
- 2) Average global temperature rises, including over the Arctic
- 3) Arctic sea ice melts, exposing dark open ocean
- 4) Less sunlight is reflected; more solar energy is absorbed by open water
- 5) The ocean and atmosphere warm even more, accelerating ice loss.

**Justification:** Step 5 returns to step 2 — this is a positive feedback because the output amplifies the original input.

**19. (1) Statements 1, 3, and 5.** A weaker/wavier jet stream + faster Arctic warming + polar-vortex disruptions linked to NY cold snaps — these together describe the Arctic-mid-latitude link. Statements 2, 4, 6 are factually incorrect.

**20. (2)**  $\approx 0.7$  million km<sup>2</sup> per decade. Drop of  $\sim 3.2$  million km<sup>2</sup> over  $\sim 4.5$  decades  $\approx 0.7$  per decade.

## Cluster 5 — Cities & Climate

**21. Statement 1:** several degrees warmer than nearby rural areas · **Statement 2:** absorb more incoming solar energy (lower albedo) · **Statement 3:** trap more outgoing infrared (long-wave) radiation, warming the lower atmosphere.

**22. (3)** CO<sub>2</sub> rose from  $\sim 315$  ppm in 1960 to over 422 ppm in 2024 — paralleling decades of industrial fossil-fuel burning.

**23. (2)** About 6 °C. Midtown  $\approx 33.7$  °C; rural baseline  $\approx 27.5$ – $27.8$  °C → difference  $\approx 5.9$ – $6.2$  °C.

**24. SUPPORT.** Trees provide shade and evapotranspirational cooling. Cool roofs have a higher albedo than dark roofs, so they reflect more solar radiation rather than absorbing and re-radiating it as heat. Both reduce the heat absorbed by the city → reducing urban heat island.

**25. (3) Observations A, D, and E.** AC heat exhaust (A), the measured rural-vs-urban gap caused by human-altered surfaces (D), and traffic waste heat / CO<sub>2</sub> (E) are all human-caused. B and F are *mitigations* (they reduce the effect), and C is global, not specifically urban.

**Grading scale (out of 25):** A = 23–25 (92–100%) · B = 20–22 (80–88%) · C = 17–19 (68–76%) · D = 15–16 (60–64%) · F = below 15.

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