

Meteorology

Team Name: _____ #: _____

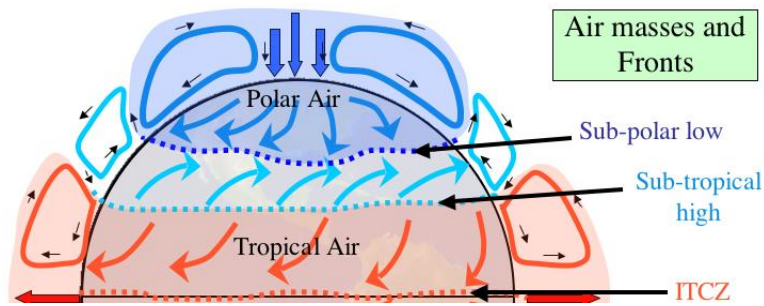
Student names: _____

Part 1 (Multiple Choice): Please write your answers in CAPITAL LETTERS on this sheet!

1. _____	17. _____	33. _____	48. _____
2. _____	18. _____	34. _____	49. _____
3. _____	19. _____	35. _____	50. _____
4. _____	20. _____	36. _____	51. _____
5. _____	21. _____	37. _____	52. _____
6. _____	22. _____	38. _____	53. _____
7. _____	23. _____	39. _____	
8. _____	24. _____	40. _____	Tiebreaker order:
9. _____	25. _____	41. _____	Q3
10. _____	26. _____	42. _____	Q8
11. _____	27. _____	43. _____	Q14
12. _____	28. _____	44. _____	Q18
13. _____	29. _____	45. _____	Q24
14. _____	30. _____	46. _____	Q29
15. _____	31. _____	47. _____	Q35
16. _____	32. _____		Q41
			Q45
			Q53

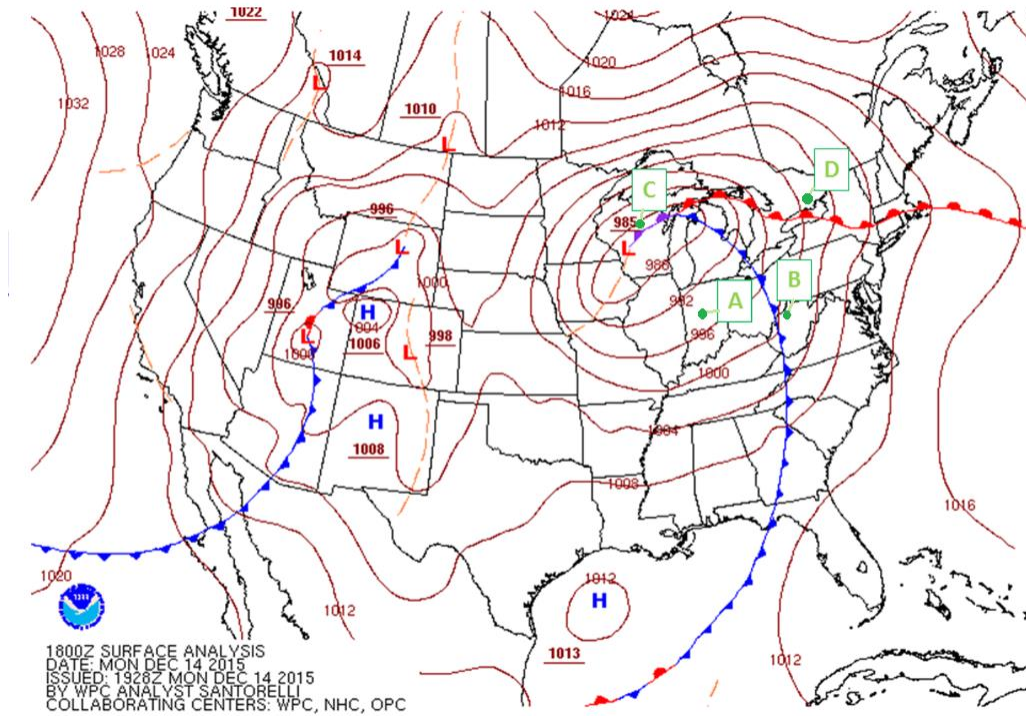
Part 2 (Free Response): Write your answers in the blank spaces between questions.

Part 1 – Multiple Choice



1. Weather systems in Michigan typically move from west to east due to the light blue winds in the diagram above. These winds are known as the
 - a. Polar easterlies
 - b. Westerlies
 - c. Trade winds
 - d. Tropical easterlies
2. "Alberta clippers" and "panhandle hooks" are both types of
 - a. Tropical anticyclones
 - b. Tropical cyclones
 - c. Mid-latitude anticyclones
 - d. Mid-latitude cyclones
3. Which of the following would *increase* the intensity of lake-effect snow?
 - a. Increasing water temperature
 - b. Increasing lake ice cover
 - c. Increasing directional wind shear
 - d. Decreasing fetch distance
4. Drylines and fronts *both* separate air masses with different
 - a. Temperatures
 - b. Densities
 - c. Humidities
 - d. Pressure
5. Which of the following is *NOT* a potential source of uplift for thunderstorm development?
 - a. Advection
 - b. Convection
 - c. Topography
 - d. Convergence

Part 1 – Multiple Choice

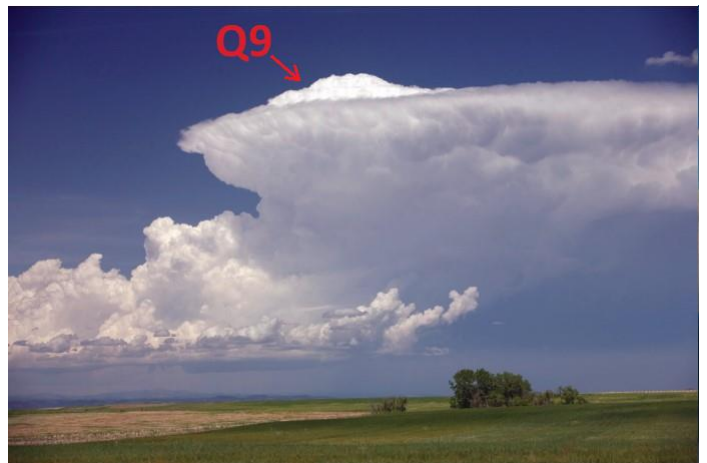


Use the image above to answer questions 6 and 7.

6. At which point is freezing rain most likely to occur?
7. Which point is most likely experiencing thunderstorms?

Use the image to the right to answer questions 8-10.

8. Which type of cloud is pictured?
 - a. Nimbostratus
 - b. Stratocumulus
 - c. Cumulus congestus
 - d. Cumulonimbus
9. The feature "Q9" points to is known as the
 - a. Overshooting top
 - b. Thunderstorm head
 - c. Cirrus plume
 - d. Cupola
10. The "Q9" feature is most indicative of
 - a. Thunderstorm rotation
 - b. Intense lightning discharge
 - c. A strong updraft
 - d. Directional wind shear



Part 1 – Multiple Choice

11. Due to melting, it is often difficult to record the size of hailstones. As a result, hail size is often reported in terms of everyday objects. Which of the following is the size of the hailstone pictured to the right?
- a. Quarter-size
 - b. Tennis ball-size
 - c. Ping pong ball-size
 - d. Penny-size

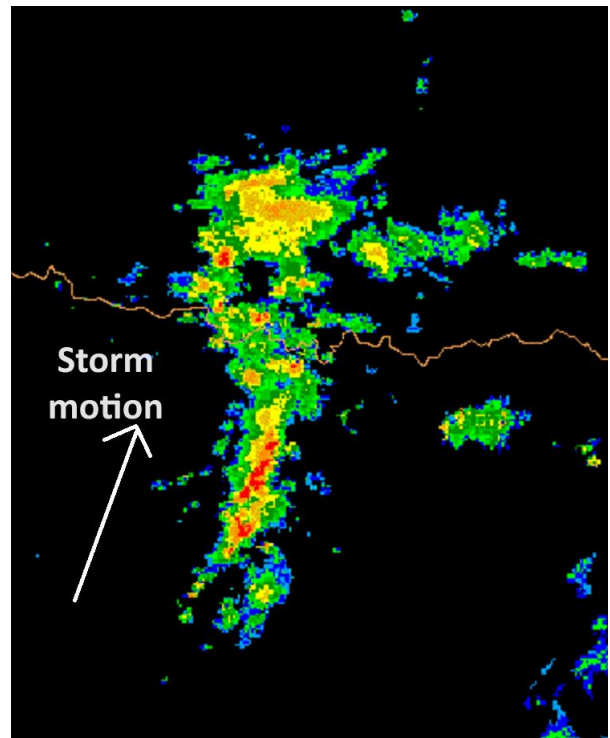


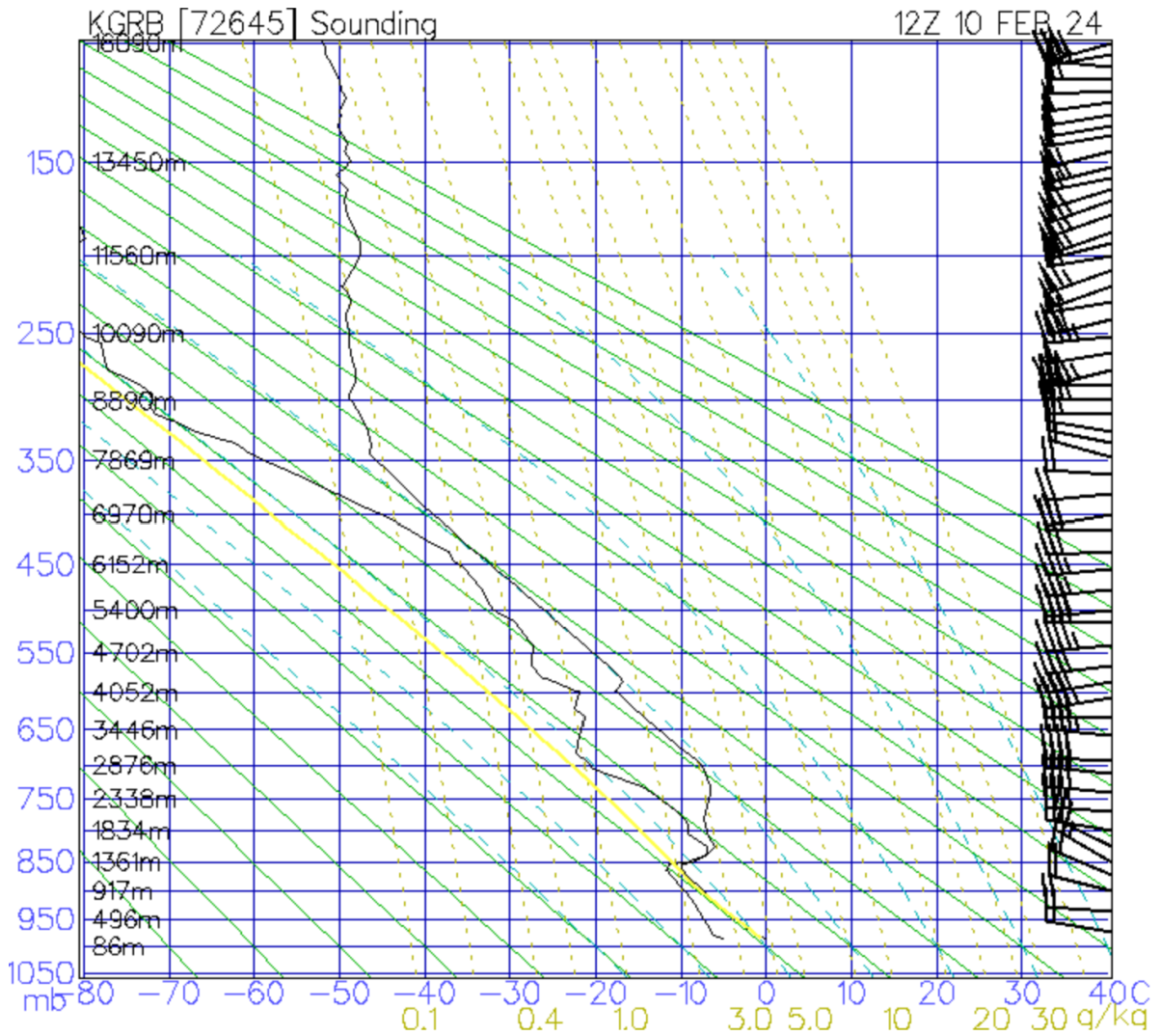
12. Hailstone size is best correlated to which of the following?
- a. Updraft strength
 - b. Cloud base temperature
 - c. Cloud base height
 - d. Thunderstorm area

13. Any thunderstorms that produce hail larger than _____ in diameter are considered “severe” by the National Weather Service.
- a. $\frac{3}{4}$ inch
 - b. 1 inch
 - c. $1\frac{1}{2}$ inches
 - d. 2 inches

Use the image to the right to answer questions 14-16.

14. Which type of thunderstorm is pictured?
- a. Single cell
 - b. Multi-cell
 - c. Supercell
 - d. Squall line
15. When thunderstorms move over the path of earlier thunderstorms (like pictured), it is known as
- a. Telescoping thunderstorms
 - b. Nesting thunderstorms
 - c. Training thunderstorms
 - d. Standing thunderstorms
16. This situation typically presents a greater risk of
- a. Flash flooding
 - b. River flooding





Use the chart above to answer questions 17-21.

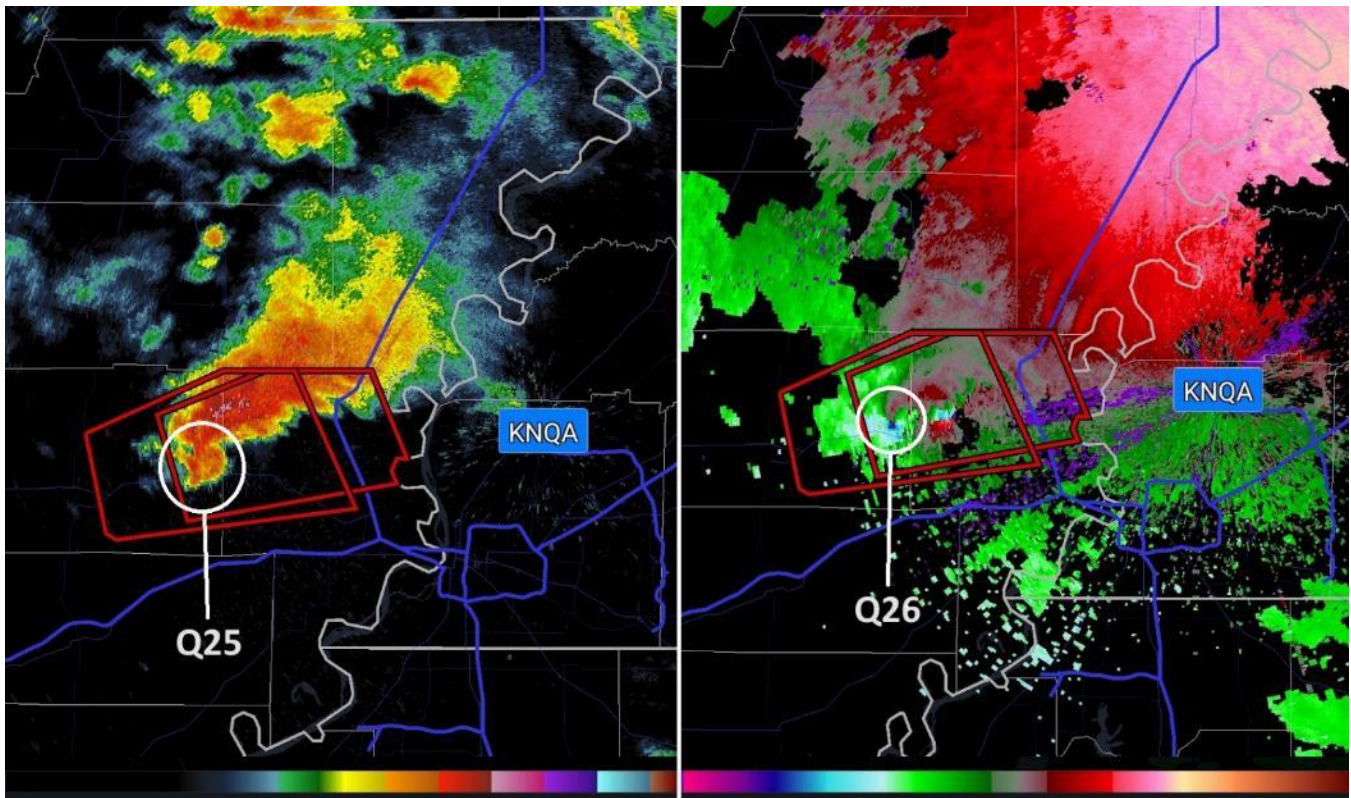
17. The chart above is known as a
- Emagram
 - Hodograph
 - Tephigram
 - Stuve diagram

18. How did meteorologists collect the data plotted in the chart?
- Radiosonde
 - Radar
 - ASOS
 - Satellite sensors

19. True or false: There is extreme directional wind shear at this location.
- True
 - False

20. Which of the following is NOT present or likely present at the 850 mb level?
- Atmospheric instability
 - Temperature inversion
 - Clouds
 - Condensation

21. Based on the data in the chart, the risk of severe storms at this location on this day is best described as
- None/marginal
 - Low
 - Moderate
 - High
 - Extreme



Use the image above to answer questions 22-27.

22. What type of thunderstorm is pictured?

- a. Single cell
- b. Multi-cell
- c. Supercell
- d. Squall line

23. What radar product quantity is shown in the image on the *right*?

- a. Radial velocity
- b. Correlation coefficient
- c. Reflectivity
- d. Storm total accumulation

24. How can radar determine that quantity shown in the *right* image?

- a. Beam attenuation
- b. Reflectivity
- c. Doppler effect
- d. Temporal ranging

25. What is the name of the phenomenon circled in the *left* image?

- a. Bounded weak echo region
- b. Hook echo
- c. Debris ball
- d. Forward flank downdraft

26. What is the name of the phenomenon circled in the *right* image?

- a. Tornado vortex signature (TVS)
- b. Mesoscale convective complex (MCC)
- c. Lagging circulation locus (LCL)
- d. Leading front of convection (LFC)

27. What is indicated by the red outlines in the images?

- a. Flash flood watch
- b. Flash flood warning
- c. Severe thunderstorm watch
- d. Severe thunderstorm warning

Use the images on the right to answer questions 28 through 30.

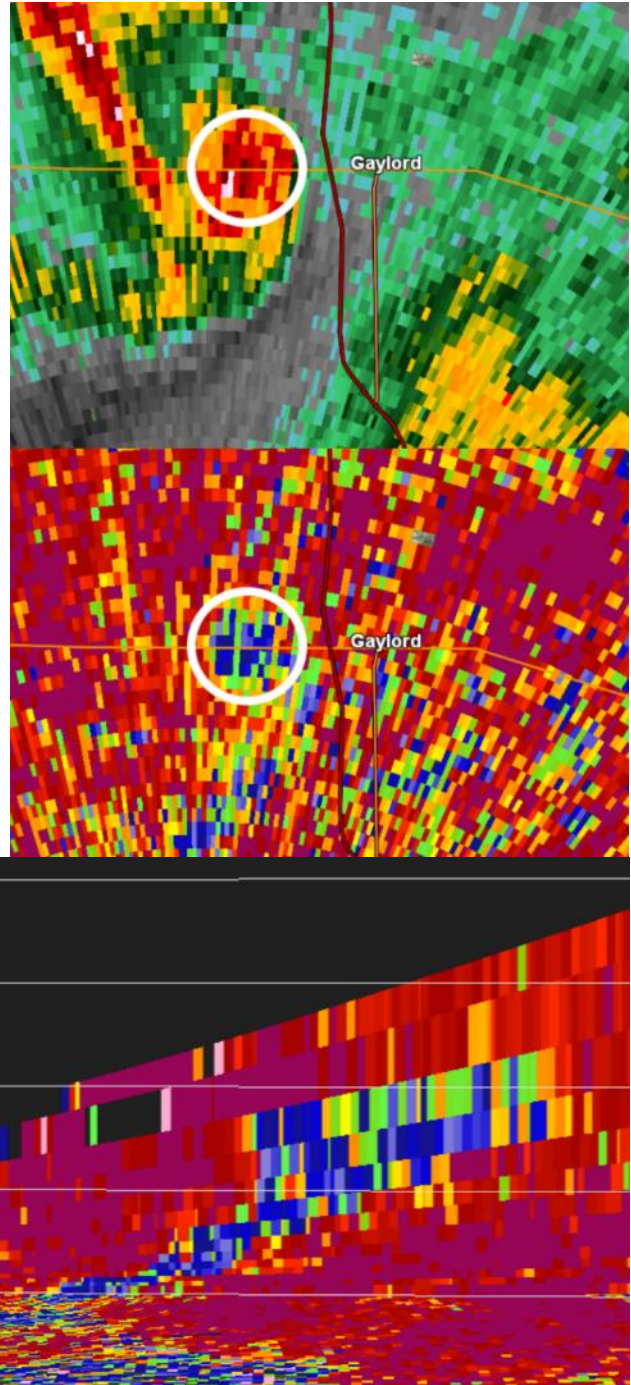
28. The top image shows how much energy was reflected back to the radar by its airborne targets. The middle image shows a quantity known as “correlation coefficient”, which shows
- Whether targets are moving in the same direction as one another
 - How likely a target is to be rain
 - How similar targets are to one another
 - Whether targets are moving towards or away from the radar

29. Given that blue colors in the middle and bottom images show low correlation coefficient, what is the circled area known as?
- Tornado vortex signature
 - Debris ball
 - Bounded weak echo region
 - Mesoscale convective complex

30. The bottom image shows a 3-D cross-section of the middle image. How far above ground level does the area of low correlation coefficient extend to?
- 10,000 ft
 - 20,000 ft
 - 30,000 ft
 - 40,000 ft

31. The Enhanced Fujita (EF) scale assesses tornadoes based on their
- Track length
 - Track width
 - Radar-measured wind speed
 - Damage to structures

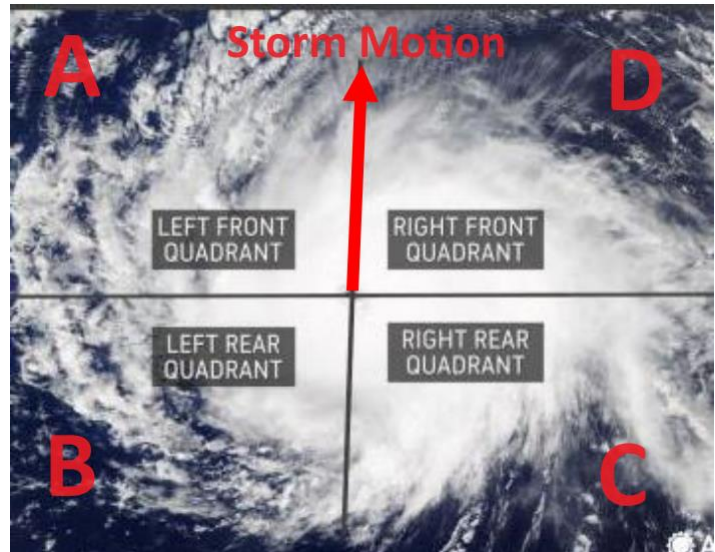
32. The tornado that struck Gaylord on May 20, 2022 was rated an EF3, meaning that its wind speeds were estimated to be between
- 86-110 mph
 - 111-135 mph
 - 136-165 mph
 - 166-200 mph



Part 1 – Multiple Choice

33. About how many tornadoes strike Michigan each year on average?
- a. 3
 - b. 13
 - c. 23
 - d. 33

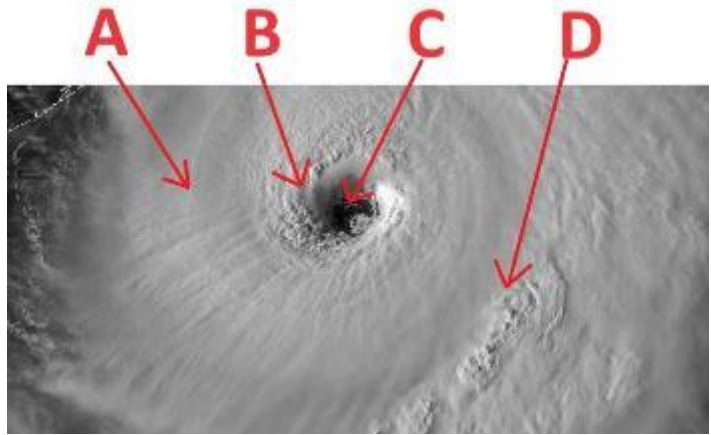
34. Tornadoes often occur within tropical cyclones. Using the diagram to the right, in which quadrant do tornadoes most often occur in the Northern Hemisphere?
- a. Left front
 - b. Left rear
 - c. Right rear
 - d. Right front



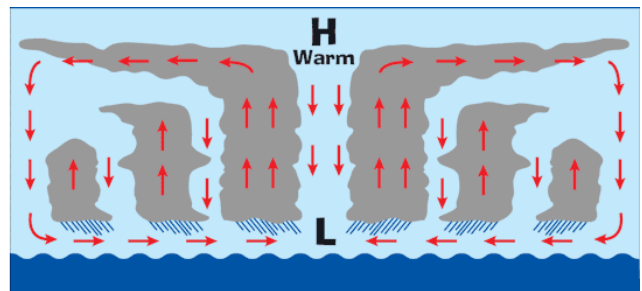
35. Tropical cyclones do not form within a few degrees latitude of the equator because
- a. Average sea surface temperatures are too low at the equator due to upwelling
 - b. There is persistent upper-level wind shear at the equator
 - c. A belt of high pressure typically occupies the equator
 - d. There is insufficient Coriolis force near the equator
36. Which of the following conditions are favorable for hurricane formation?
- a. Strong speed wind shear
 - b. Strong backing directional wind shear
 - c. Strong veering directional wind shear
 - d. Weak wind shear
37. Tropical cyclones in the North Atlantic often develop from a trough of low pressure called a
- a. Atlantic ridge
 - b. Azores disturbance
 - c. Tropical wave
 - d. Saharan depression
38. Hurricanes and typhoons are different in that
- a. They rotate in opposite directions
 - b. They have significantly different wind speeds
 - c. They occur in different locations
 - d. They are different sizes

Part 1 – Multiple Choice

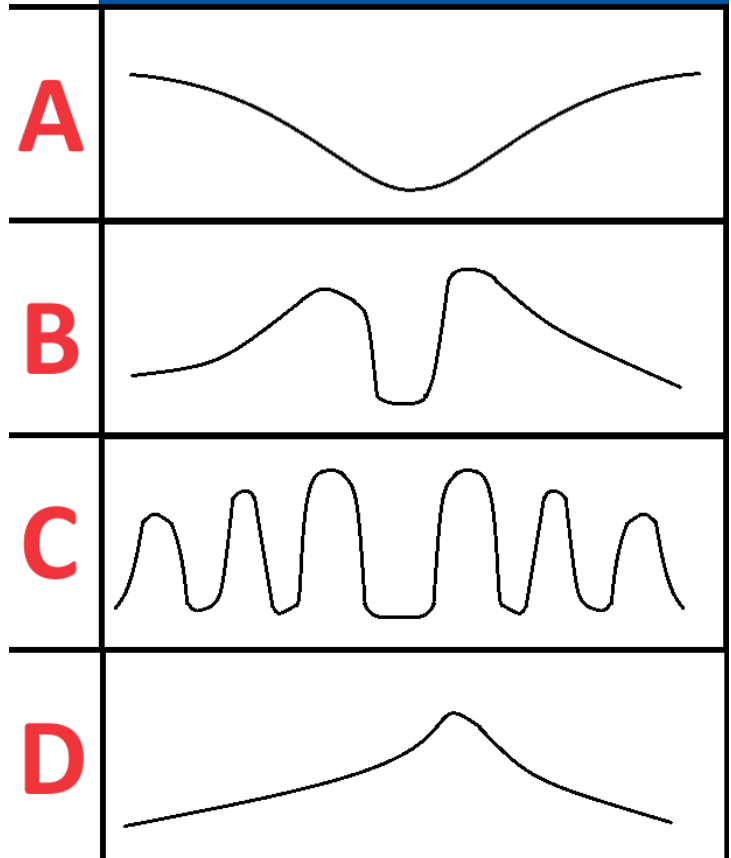
39. Which letter in the image to the right points to the eyewall?



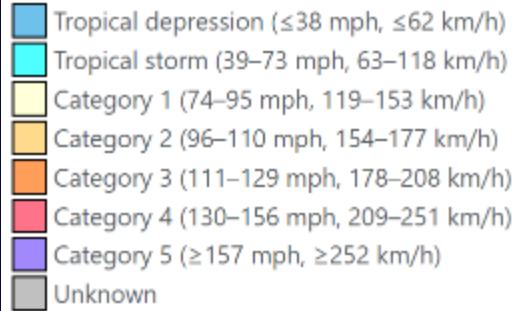
For questions 40-43, match each hurricane characteristic to its corresponding cross section graph to the right. Letters may be used more than once or not at all.



- 40. Rainfall intensity
- 41. Sea-level pressure
- 42. Surface wind speed
- 43. Storm surge



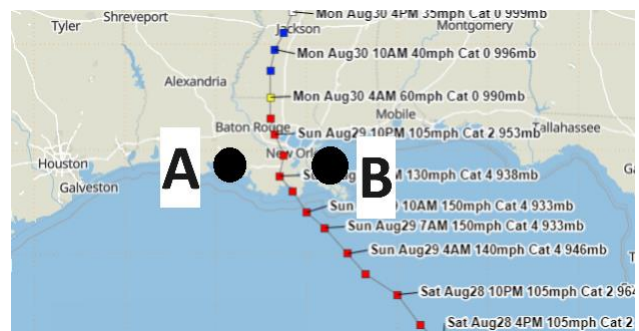
Part 1 – Multiple Choice



44. Shown above is the track of Hurricane Henri in 2021. Which of the following best explains how Hurricane Henri was able to intensify to hurricane strength so far northwards?
- Henri grew smaller, allowing winds rotating around the eye to move faster
 - Henri moved into an area with strong directional wind shear
 - Henri’s path coincided with a warm ocean current
 - Henri merged with an intense “bomb” cyclone that had moved offshore a day earlier

Use the image to the right to answer questions 45-47.

45. Shown to the right is the track of Hurricane Ida. Given that the hurricane was moving about 15 mph upon landfall, what was the approximate difference in wind speed between point A and B?
- 0 mph
 - 7.5 mph
 - 15 mph
 - 30 mph



46. Which point has the higher wind speed?
- A
 - B
 - Both wind speeds are the same
47. Which point would have the higher wind speed if Earth rotated in the opposite direction around its axis?
- A
 - B
 - Both wind speeds would be the same

Part 1 – Multiple Choice

48. Which of the following weather events causes the most casualties in the United States annually?
- a. Tornadoes
 - b. Flooding
 - c. Extreme Heat
 - d. Strong winds
49. Most fatalities due to flash flooding in the US occur in
- a. Vehicles
 - b. Homes
 - c. Commercial businesses
 - d. Public service buildings
50. Many severe weather fatalities occur indirectly due to carbon monoxide poisoning from improper generator use. To prevent this, only use generators outside, at least _____ feet from a building.
- a. 5
 - b. 10
 - c. 20
 - d. 75
51. A suitable room for taking shelter from a tornado would have all of these characteristics *EXCEPT*
- a. Large
 - b. Windowless
 - c. Interior
 - d. On the lowest floor
52. The most dangerous hazard presented by hurricanes is historically
- a. High winds
 - b. Storm surge
 - c. Lightning
 - d. Tornadoes
53. Prior to resuming outdoor activities after a thunderstorm, lightning or thunder must not be observed for at least how long?
- a. 5 minutes
 - b. 10 minutes
 - c. 15 minutes
 - d. 30 minutes

A tornado struck the town of Science Olympia, Iowa. Use the images of damage caused by the tornado along with the accompanying wind speed estimate tables to answer questions 54 through 58 on the following page.



"ONE-AND TWO-FAMILY RESIDENCES"

		Expected wind speed
DOD*	Damage description	EXP
1	Threshold of visible damage	65
2	Loss of roof covering material (<20%), gutters and/or awning; loss of vinyl or metal siding	79
3	Broken lams in doors and windows	96
4	Uplift of roof deck and loss of significant roof covering material (>20%); collapse of chimney; garage doors collapse inward; failure of porch or carport	97
5	Entire house shifts off foundation	121
6	Large sections of roof structure removed; most walls remain standing	122
7	Top floor exterior walls collapsed	132
8	Most interior walls of top story collapsed	148
9	Most walls collapsed in bottom floor, except small interior rooms	152
10	Total destruction of entire building	170

* Degree of Damage



"MANUFACTURED HOME – DOUBLE WIDE"

		Expected wind speed
DOD*	Damage description	EXP
1	Threshold of visible damage	61
2	Loss of shingles or other roof covering (<20%)	76
3	Damaged porches or carports	78
4	Broken windows	83
5	Uplift of roof deck and loss of significant roof covering material (>20%)	88
6	Complete uplift of roof; most walls remain standing	93
7	Unit slides off CMU block piers	94
8	Removal of entire roof structure leaving most walls standing	97
9	Complete destruction of roof and walls leaving undercarriage in place	113
10	Unit rolls, displaces or vaults	114
11	Undercarriage separates from floor, rolls and tumbles, badly bent	127
12	Complete destruction of unit; debris blows away	134

* Degree of Damage



"ELEMENTARY SCHOOL"

		Expected wind speed
DOD*	Damage description	EXP
1	Threshold of visible damage	65
2	Loss of roof covering (<20%)	79
3	Broken windows	87
4	Exterior door failures	99
5	Uplift of some roof decking; significant loss of roofing material (>20%); loss of rooftop HVAC	101
6	Damage to or loss of wall cladding	108
7	Uplift or collapse of roof structure	125
8	Collapse of non-bearing walls	139
9	Collapse of load-bearing walls	153
10	Total destruction of a large section of building or entire building	176

* Degree of Damage

Part 2 – Free Response

54. What wind speed is estimated for the image of damage to One- and Two-Family Residences? (1 pt)

55. What wind speed is estimated for the image of damage to Double-Wide Manufactured Homes? (1 pt)

56. What wind speed is estimated for the image of damage to the Elementary School? (1pt)

57. Using the maximum estimated wind speed from the three images and the chart below, what EF rating was this tornado? (1 pt)

EF SCALE	
EF Rating	3 Second Gust (mph)
0	65-85
1	86-110
2	111-135
3	136-165
4	166-200
5	Over 200

58. Unaware of the severe weather risk, Jaylin was driving in his car when the tornado struck. In the tornado's path and unable to get to shelter, what should he do to protect himself? (2 pts)

Part 2 – Free Response

The image below shows the track of Hurricane Idalia as it moved northwards, making landfall in Florida. Use the image with the tidal data on the following page to answer questions 59 through 64.

59. Which location(s) had a Storm Surge Warning issued? (1 pt)

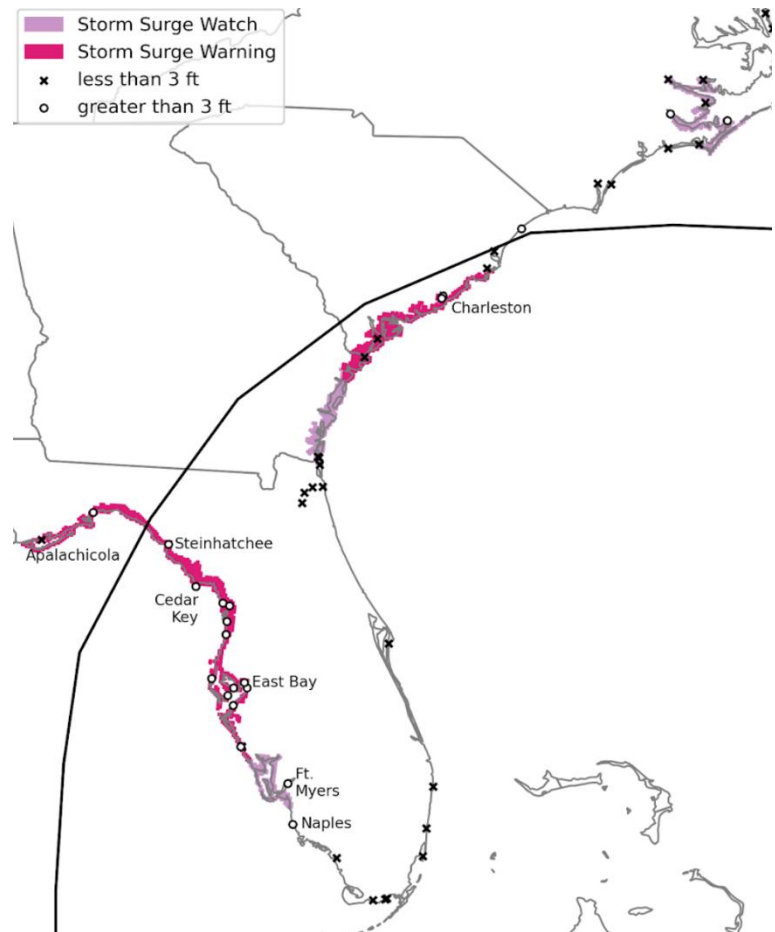
60. Which location(s) did NOT experience tropical storm-force winds? (1 pt)

61. Which location was the last to have a Storm Surge Watch issued? (1 pt)

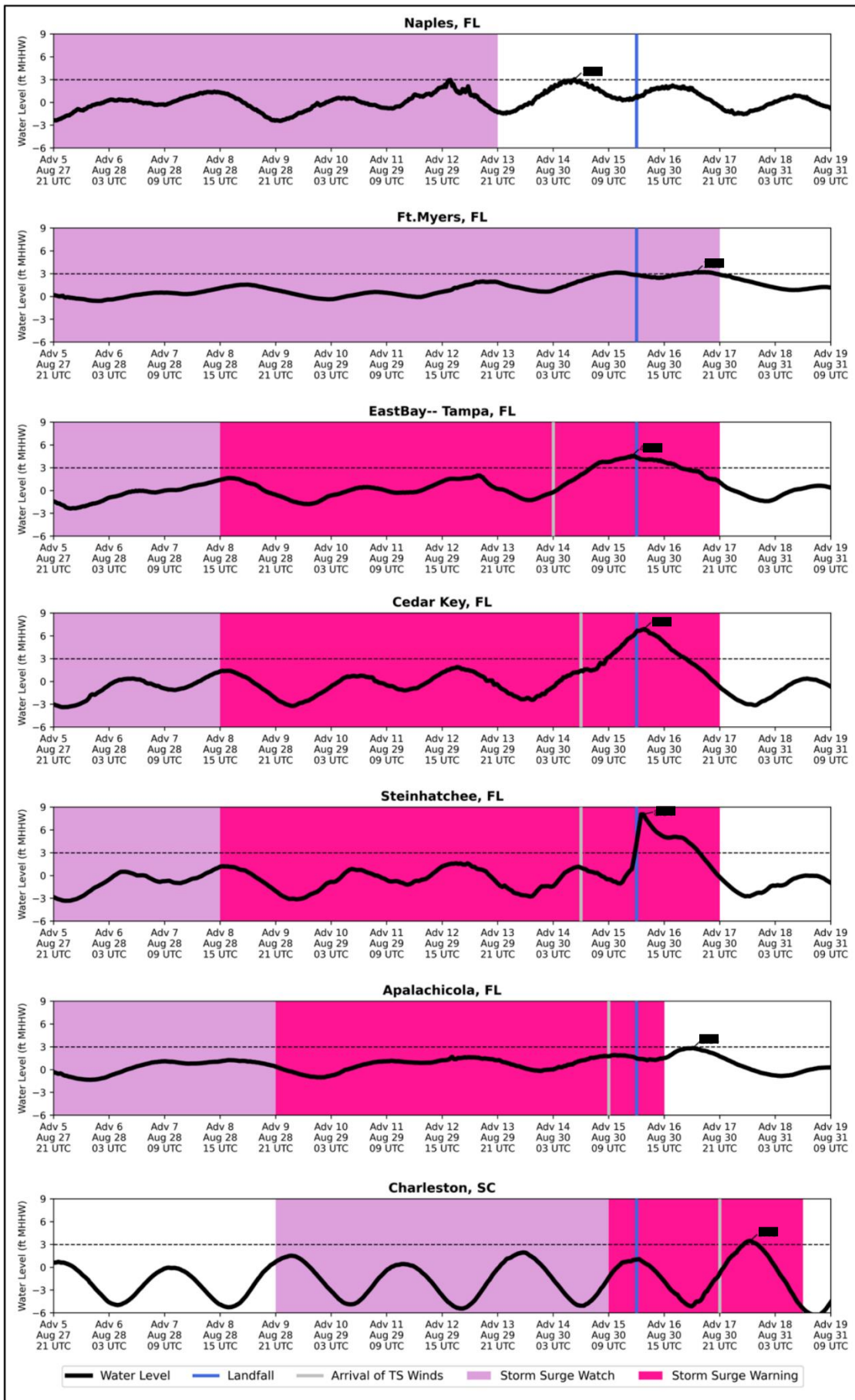
62. Which location experienced the most extreme storm surge relative to its mean higher high water (MHHW) level? What was the approximate height of that storm surge? (2 pts)

63. Why did that location have the most extreme storm surge? (2 pts)

64. Other than hurricane intensity, what is a factor that could affect the height or destructiveness of storm surge? (1 pt)



Part 2 – Free Response



Part 2 – Free Response

Use the images to the right to answer questions 65 through 69.

65. What does the instrument shown in the top right picture measure? (1 pt)



66. What type of waves does that instrument use? (1 pt)

67. What does the instrument shown in the middle right photo measure? (1 pt)



68. What does the instrument in the bottom right photo measure? (1 pt)



69. All of these instruments are important components of an ASOS station. What is ASOS an abbreviation for? (1 pt)