Introduction to Meteorology
ATMS 103 – Fall 2022
Study Guide for the Final Exam

The following is not intended to be a comprehensive list of everything that may appear on the final exam, but I have tried to put together some questions that will guide you toward an understanding of the subjects we've covered over the course of the semester. I anticipate that *approximately* 60% of the content of the final exam will address the topics introduced since the previous exam. All of the information from the entire course is fair game for the final exam, particularly the more difficult concepts that are necessary to understand interesting weather processes. It would be a very good idea to look over the homework assignments, read the book, review the NWS Jetstream Thunderstorm and Tropical Weather topics as a study tool, and of course review the class notes. I expect that you will have viewed all of the class lecture videos and/or attended class. Bring a calculator to the exam, but do *not* use a cell phone, the Internet (besides the Moodle page), or book. Do not memorize equations, but do know how to use them. You will receive an equation sheet similar to the one at the end of this study guide if needed. The exam will take place via Moodle on **1 December 2022 (Section 1: 1:20 p.m.)** or **6 December 2022 (Section 2: 3:15 p.m.) at 11:30 a.m.** You must take the exam with your enrolled section. As always, ask questions and good luck!

Topics from the first third of the semester:

1. Geography is essential to the study of meteorology. Make sure you know where states and oceans are located (see the states quiz study guide for help).
2. What is the difference between the hydrosphere, lithosphere, biosphere, cryosphere, and atmosphere and what kind of scientists study each?
3. What are the main gases in the modern atmosphere and what are their concentrations by volume?
4. Understand the units and meaning of velocity, acceleration, force, pressure, work, density, and temperature. Be able to manipulate and convert these units in calculations.
5. How do you convert between different units of temperature and what are the boiling and freezing points of water using each scale?
6. What holds the atmosphere in place?
7. What property of the atmosphere always decreases with height, no matter what?
8. What are the layers of the atmosphere and how do we define them?
9. What is the tropopause? How would we find it?
10. What is a lapse rate?
11. Understand how energy is always conserved and how it is converted into different forms.
12. How is heat transferred in the processes of conduction and convection?
13. What is the hydrologic cycle?
14. Understand the concepts of saturation and moist processes in the atmosphere, including relative humidity, different measures of humidity, condensation nuclei, Dalton's Law, dewpoint, and how to measure atmospheric moisture.
15. How many physical states can water have in the atmosphere? What is the type of energy that is absorbed or released as water changes phase? How does this affect the atmosphere?
16. What are the laws of radiation and how are they used? Identify which laws pertain to which parts of a plot of radiative intensity vs. wavelength.
17. What is the Earth's energy budget and what happens if the balance is changed?
18. What is the greenhouse effect?
19. Why does Earth have seasons? (NOTE: It's *not* because of the Earth–Sun distance!)
20. Where and when can the sun be directly overhead? What is the Tropic of Capricorn and what is the Tropic of Cancer and where are they located? Why are they located there?
21. Understand surface and upper-air measurements, how atmospheric properties are observed, and how to read a surface station plot.
22. What are the forces that affect horizontal motion?
23. What causes the wind to blow?
24. Be able to deduce the wind direction based on a pressure field drawn for a particular hemisphere at a particular height above the surface.
25. What is the difference between gradient, geostrophic, and cross-isobaric flow?
26. What is Buys-Ballots's Law and how do you use it?
27. Where in the atmosphere does friction play a role in the force balance and where can it be ignored?
28. What are convergence and divergence and what role does each play in the formation of cyclones and anticyclones?
29. Locate troughs, ridges, upper-level divergence, and upper-level convergence on an upper-air map.

30. Why do surface high and low pressure systems tend to move in a certain direction?

Topics from the second third of the semester

31. How does a Doppler radar work and how do you calculate the distance to a reflective object? What is the Doppler effect and how do we use it in meteorology? What is a WSR-88D and where might you see data from its measurements?
32. What is the difference between visible, infrared, and water vapor satellite imagery? What are we seeing in each image?
33. What is a lapse rate? What are the standard, dry adiabatic, moist adiabatic, and environmental lapse rates and how do you use them?
34. What is atmospheric stability and what does it have to do with thunderstorms?
35. Which processes are diabatic and which are adiabatic processes?
36. What causes stable (unstable) air?
37. What are the LCL and LFC?
38. Given an environmental lapse rate (or an observed sounding), how do you tell if the atmosphere is stable, unstable, or conditionally unstable?
39. What happens to an air parcel when it sinks (rises)?
40. What is the ideal gas law? Which variables depend on each other when governed by this law?
41. What is hydrostatic balance?
42. How might latent heating in mid-levels lead to lower pressure at the surface? How might radiational cooling lead to higher pressure at the surface?
43. What is the relationship between jet streaks and midlatitude cyclones (i.e., at the surface)? How does a jet streak affect upper-level vertical motion?
44. Why do pressure systems dissipate?
45. What is an air mass and what are source regions?
46. How are air masses classified?
47. Know the difference between each type of front, how it's drawn on a weather map, and what weather is typically associated with each type of front before, during, and after its passage.
48. Identify a cold front from a meteorogram.
49. What are three types of thunderstorms and what are the typical characteristics of each?
50. How does the NWS define a severe thunderstorm?
51. Define each stage in the life cycle of an ordinary thunderstorm.
52. What are different lifting mechanisms that may initiate thunderstorms?
53. List the necessary atmospheric ingredients for thunderstorms.
54. Define and understand the structure of each of the following: MCC, MCV, MCS, bow echo, squall line, and derecho.
55. What is a gust front, how does it form, and what clouds are associated with it?
56. What is special about a supercell compared with other thunderstorms?
57. How are supercells classified (three types)?
58. What is the horizontal and vertical structure of a supercell?
59. What is the difference between a watch, a warning, an advisory, and a statement?
60. Who issues different types of watches and warnings (e.g., hurricane/severe thunderstorm/tornado watches and warnings)?
61. What's special about SAME technology?
62. What geographic areas are covered by watches and warnings?
63. What is an outlook and what information does it provide? Who cares about it?
64. What is the *best* way to receive urgent weather information?

Topics from the last third of the semester

65. What makes lightning and thunder?
66. What are the steps to a lightning discharge? Which step do we see?
67. How do you stay safe during a thunderstorm?
68. How far away is a lightning strike if you hear the thunder 10 seconds after you see the flash?
69. Where do the most thunderstorms occur in the U.S.? Where do the most tornadoes occur?
70. Review the questions from the *Thunderstorm Quiz*.
71. Review the questions from the *Tropical Weather Review Quiz*
72. Are sleet, snow, graupel, and hail the same thing?
73. What causes hail to form? Which storms typically produce hail?
74. Hail grows by what mechanisms? What affects hail size?
75. Where does hail fall in a typical supercell thunderstorm?
76. What parameters do we look for when forecasting hail?

77. Can water exist below freezing (i.e., 0°C)?
78. How do meteorologists rate tornadoes? How is the EF-scale different from the F-scale?
79. When (time of day and time of year) do most tornadoes occur and why?
80. How do you apply the conservation of angular momentum to tornado formation?
81. Know the difference between translational and rotational velocity and apply your knowledge.
82. What are the different tornado formation mechanisms?
83. What are other types of small-scale vortices and how are they different from tornadoes?
84. What should you do to stay safe if a tornado is approaching your vehicle or home? What should you *not* do?
85. What are the three main cells in the general circulation model?
86. What is the ITCZ, where is it, and why is it there?
87. How do ocean currents affect regional climate?
88. What is upwelling and why does it occur?
89. Why are the world's deserts located at nearly the same latitude?
90. What is the Walker circulation and what is its relation to El Niño?
91. What are the steps necessary to get to an El Niño event from a normal Walker circulation?
92. What's the difference between El Niño and La Niña and what happens during each?
93. How do Equatorial Pacific SST anomalies affect hurricane development in the tropical Atlantic?
94. How do El Niño and La Niña affect the weather in the United States?
95. Describe the tropics.
96. What are the formation mechanisms of tropical cyclones and what are the optimal conditions for tropical cyclone development?
97. When is hurricane season?
98. What are the stages of tropical cyclone development and what are the naming conventions?
99. Explain the positive feedback cycle in tropical cyclone formation.
100. What are the wind speed thresholds for tropical storms and category 1-5 hurricanes?
101. What is the name of the hurricane intensity scale?
102. What are tropical cyclones called around the world and in what part of the world are they most prevalent?
103. What is the structure of a hurricane and how do these features form? Identify the central dense overcast, spiral rain bands, rain-free area, eye wall, and eye.
104. What is storm surge, how does it form, and what are its impacts?
105. What is responsible for the most deaths in hurricanes? Where do these deaths take place?
106. What do hurricane watches and warnings mean and who issues them?
107. Why do tropical systems move from east to west? Why do they recurve?
108. What happens to the sea surface temperature when tropical cyclones pass? Why does this happen and how could it affect subsequent storms?
109. What is the difference between weather and climate?
110. What factors influence regional temperatures?
111. What factors influence regional precipitation?
112. What ultimately drives Earth's entire climate system?
113. What is a climate "normal"?
114. What is the Köppen system?
115. In what ways can we determine past climates?
116. What types of evidence can we use to determine that climate changes?
117. List several natural factors that can cause climate change.
118. Milankovitch theory describes the collective effect of changes in what three orbital parameters?

Some potentially useful equations and constants:

$F = ma$

$\frac{\partial p}{\partial z} = -\rho g$

$\Gamma = -\frac{dT}{dz}$

$p = \rho R_d T$

$p\alpha = R_d T$

$C = 2\Omega v \sin\phi$

$\frac{\partial \rho}{\partial t} = -\vec{\nabla} \cdot \rho\vec{V}$

$KE = \frac{1}{2}mv^2$

$\Phi = g\Delta z$

$^\circ C = \frac{5}{9}\left(^\circ F - 32^\circ\right)$

$K = °C + 273.15$

$c = f\lambda$

$Z = 300R^{1.4}$

$\theta = T\left(\frac{p_0}{p}\right)^\kappa$

$\lambda_{max} = \frac{2897\,\mu mK}{T}$ T in Kelvin

$E = \varepsilon\sigma T^4$

$2d = ct$

$\Gamma_d = 9.8°C/km$

$\Gamma_m \approx 6.0°C/km$

$\sigma = 5.67 \times 10^{-8}\ \frac{W}{m^2\ K^4}$

$c = 2.9979 \times 10^8\ \frac{m}{s}$

$RH = \frac{e}{e_s} \times 100\%$

$c_p = 1004\ \frac{J}{kg\ K}$

$S_o = 1367\ \frac{W}{m^2}$

$°F = \left(\frac{9}{5}°C\right) + 32$

$\Omega = 7.292 \times 10^{-5}\ s^{-1}$

$V_1 r_1 = V_2 r_2$