READ THIS FIRST: This is the finalized study guide for midterm 1, spring 2011. The outline below is not meant to be fully comprehensive. It lists the major topics that we discussed in class, but it does not completely cover everything involved with every topic. You should use this as a guide to your notes, and to what to look at in the text. The midterm will cover chapters 1, 2, 3 and 4 through humidity (adiabatic temperature changes and atmospheric stability will not be included on the exam). The midterm will take place on Monday February 7. All students must take the exam during regular class time in the regular classroom. The exam will not be available at the testing center. You must take the exam the day listed here for your section unless you have made other arrangements with Prof. Bunds.

INSURANCE: As noted on the syllabus, you must complete all the recommended questions from the textbook (listed on the syllabus – you don’t need to do the questions on adiabatic temperature changes or atmospheric stability) as well as the questions attached to this study guide and hand them in by the end of the testing period you’re your section. For more information, see the course syllabus.

CHANGES FROM PRELIMINARY STUDY GUIDE: Changes are minimal and include noting that the exam will be available in class only and not at the CTC, removing the outline information on adiabatic temperature changes and atmospheric stability, and removing study questions 52-60.

1. Introduction – Chapter 1
   a. What is meteorology?
      i) It is the study of the atmosphere
      ii) It utilizes the scientific method (you should know what the scientific method is and how it works – observations, hypotheses, scientific theories)
      iii) meteorology includes the study of both climate and weather
   b. Weather
      i) temperature, cloud cover, wind, precipitation, air pressure, humidity
      ii) in weather, need to consider the above factors at a range of elevations – not just Earth’s surface
      iii) Also pollution (including allergens)
   c. Climate
      i) Long-term weather, effectively
      ii) Note that ‘the climate’ in an area is in a sense a moving target – it is constantly changing
   d. Both weather and climate include the following endeavors:
      i) Observing (measuring and describing, using tools such as barometers, thermometers, anemometers, weather balloons, radar, satellite images
      ii) Analyzing – for example, any generalized pattern (precip, winds, heat wave), low pressure centers, fronts, etc.
      iii) Forecasting – what will the weather be like in the future? – temp, wind, precip, cloud cover, pressure(!), etc.
   e. The Scientific Method
      i) Purpose – conceptually organize, explain, understand, predict the world around us
      ii) The method
         (1) Identify a phenomenon or phenomena that we wish to understand better, for example
            (a) origin and location of mountains, volcanoes and earthquakes; seasons, movement of planets and stars; locations and movements of large winter throughout northern U.S. storms
         (2) Form a hypothesis about the phenomena
            (a) the hypothesis answers the question in (1) above
            (b) the hypothesis must be consistent with available information
            (c) the hypothesis must be able to be tested by further inductive (observations) and deductive analysis (calculations; must be consistent with all known natural laws and theories).
         (3) If a hypothesis passes many, many, many tests and fails none, it becomes a THEORY
            (a) Be sure to understand that in science, a THEORY is like fact – it is supported by overwhelming amounts of evidence, and there are no observations with which it conflicts
            (b) Our examples
               (i) plate tectonics
               (ii) evolution; natural selection
               (iii) Earth and planets orbit the sun
               (iv) origin of seasons from orbit of Earth; frontal systems
   f. Understand the concepts of the interlinked Atmosphere and Hydrosphere
   g. Causes of Weather and climate
      i) the Sun! plus seasonal changes
indirectly, heat from within the Earth, via volcanoes etc. (for example dust from volcanoes can affect weather and possibly climate.

h. Composition of the Atmosphere – you should know the major constituents:
   i) nitrogen (N₂) – 78%
   ii) oxygen (O₂) – 21%
   iii) Ar – 1%
   iv) CO₂, Ne, He, CH₄, Kr, H₂ all are minor but important constituents of the atmosphere.
   v) H₂O 0.4%
   vi) Aerosols (i.e., dust)

i. Thickness and distribution of pressure in the atmosphere
   i) The atmosphere has no ‘top’
   ii) 50% of air below about 6 km altitude
   iii) 90% below about 18 km
   iv) only 0.00003% of air is above 100 km elevation

j. Thermal structure of the atmosphere – from the bottom up
   i) Troposphere
      (1) 0 to about 10 km
      (2) Where weather happens
      (3) temperature decreases with increasing altitude
      (4) heated by the ground
      (5) well mixed by weather-related air movements
   ii) Tropopause
      (1) boundary between troposphere and stratosphere
      (2) 9 km ht. in polar regions
      (3) 10.5 km midlatitudes
      (4) 17 km in tropics (more sunlight, more heating)
   iii) Stratosphere
      (1) temperature fairly constant throughout lowest 10 km of stratosphere
      (2) temperature generally increases with increasing altitude above about 20 km
      (3) heated directly by solar radiation because ozone in stratosphere absorbs ultraviolet light and converts much of it to heat energy – parts closer to sun receive the most uv light, and consequently are warmer (much uv light is absorbed before it reaches the lower stratosphere
   iv) Mesosphere
      (1) temperature decreases with increasing height
      (2) we don’t know a tremendous amount about it because balloons cant get that high, satellites cant get that low
   v) Mesopause
      (1) boundary between mesosphere and thermosphere
      (2) about 80 km in height
   vi) Thermosphere
      (1) extends from mesopause upwards; no well-defined upper limit
      (2) temperature increases with height
      (3) heated by high-energy, short-wave radiation absorbed directly by N₂ and O₂

k. Compositional variations with altitude
   i) virtually none below the mesopause (80 km height)
   ii) Ionosphere
      (1) 80 to 400 km
      (2) N₂ and O₂ atoms are stripped of electrons by the high-energy, short-wavelength radiation, creating ions that can flow and create electric currents. This creates the aurora borealis and aurora australis

2. Solar Heating – Chapter 2
   a. Intro
      i) solar heating causes weather
      ii) Amount of solar heating varies at any given time by latitude
      iii) Amount of solar heating varies at any given place over time (day vs night seasons)
      iv) atmospheric absorption
      v) re-radiation by earth’s surface
   b. Understand what sunlight is and how the intensity of solar radiation varies as function of wavelength (i.e., how much radiation reaches earth in each wavelength)
   c. Latitudinal variations in intensity of solar heating
i) Variation in the angle at which light hits the Earth’s surface is the biggest factor, because:
   (1) low angle distributes light over greater area
   (2) more reflection (secondary effect)
ii) length of day (can be very short in winter at high latitudes)
d. Seasonal variations – understand the following concepts
   i) 23.5° inclination of Earth’s spin axis
   ii) orbit of earth around sun
   iii) solstices and equinoxes
   iv) variations in sun angle with seasons (73.5 max at summer solstice; 26.5 min noon winter solstice in Utah)
   v) variations in length of day with seasons (9hrs min.; 15hrs max 40oN, which is where we live)
   vi) equator, tropic of cancer (23.5 north), tropic of Capricorn (23.5 south)
e. What happens to incoming solar radiation
   i) 50% absorbed by land & sea (converted to heat)
   ii) 20% absorbed by atmosphere and clouds (mostly converted to heat)
   iii) 30% lost back to space by reflections and scattering
   iv) concept of albedo; high albedo means lots of light reflected.
      (1) snow = high albedo, up to 90%
      (2) water 5 to 80% depending on sun angle
      (3) clouds 25 to 85%
      (4) forests, land (rock, dirt), 5 to 25%
f. Earth’s radiation
   i) all objects radiate according to temp
      (1) hotter => more intense and shorter wavelength radiation
   ii) relatively cool earth mostly radiates long wavelength infrared (10µ)
g. Atmospheric absorption and the greenhouse effect
   i) Atmos. is very transparent to visible light
   ii) Atmos. is moderately opaque to infrared
   iii) atmos acts like a blanket by inhibiting escape of infrared; earth got warmer, emits enough infrared that the percent
        that does escape equals amount of energy received from sun
3. Temperature – Chapter 3
   a. One of most noticeable and important aspects of weather.
   b. Types of measurements of temperature that people commonly make and/or calculate
      i) current temperature
      ii) High temperature for the day
      iii) Low temperature for the day.
      iv) daily mean temperature: average of high and low or average of 24 measurements, one taken each hour
      v) daily temperature range = high – low
      vi) monthly mean (average of all daily averages for the month)
      vii) annual mean (average of monthly means)
      viii) annual temp range = (highest monthly mean) – (lowest monthly mean)
      ix) “normal” temperature is average over past thirty years
   c. Displaying temperatures on graphs and charts
      i) time series displays temp at a single place over a time period
      ii) isotherms – temp over a range of places at a given time
d. What controls temperature at a place? Several important controls:
   i) latitude
   ii) land and water heat up differently from same sunlight
   iii) ocean currents
   iv) altitude
   v) geographic position (and winds)
   vi) cloud cover and albedo
e. Heating of land and water by the sun,
   i) land heats up much more than water from same amount of sunlight cools off much more in absence of sunlight –
      because
      (1) has much lower heat capacity – explain heat capacity
      (2) rock is opaque and doesn’t move/circulate to distribute sunlight energy over a thicker layer like water often does
      (3) evaporation
      (4) land has a lower albedo in general
   ii) lots of water in area tends to moderate temperatures – area stays cooler in the day, warmer at night
f. **Altitude**

i) As we have seen, temperature decreases about 3.5°C per 1000 feet altitude in troposphere because air is heated primarily from land below. So the higher you go, the cooler it is.

ii) Occasional this reverses – reverse situation is called a temperature inversion – recent example:

(1) 31°F at 4500 ft
(2) 28°F at 5300 ft
(3) 44°F at 8000 ft
(4) 40°F at 9600 ft

iii) Be aware that we discussed inversions along the Wasatch front in class, including their causes and effects:

(1) High pressure blocks circulation (winds) and contributes to sinking of air
(2) Cold air from mountains sinks into valleys
(3) Cold air remains trapped in valleys
(4) Presence of the inversion blocks movement of air out of the valleys; air cannot easily rise to escape
(5) Over time pollution builds

g. **Geographical Position**

i) Primary thing here is location near or away from large bodies of water.

ii) Also whether prevailing winds blow from water over land or vice versa.

iii) In US, winds mostly come from west, therefore S. Francisco is greatly affected by water, New York much less so.

h. **Cloud Cover and albedo effects**

i) Cloud cover greatly moderates temperatures

(1) Blocks sunlight during day, keeps temps lower
(2) Blocks escape of earth's infrared radiation at night, keeps things warmer

ii) Albedo – snow on the ground helps keep things cooler by reflecting sunlight

i. **World temps and currents**

i) Use January and July temp figs to illustrate:

(1) Latitudinal variations
(2) Seasonal variations
(3) Current and prevailing wind effects

j. **Temp Cycles**

i) Daily max and min lags behind peaks (and mins) of incoming radiation

(1) Land keeps heating into the afternoon, so temp max is typically not long before sunset
(2) Land (and air) cools all night, so low is just before or right at sunrise

ii) Same sort of effect with seasons

(1) Late July often hottest time, one month or so after summer solstice
(2) Late January is often coldest time, one month after winter solstice

iii) Humidity and water (lakes, oceans) tend to moderate day to night differences

k. **Human perception of heat and affects of heat & cold on people**

i) How hot or cold we feel, and health risks from hot and cold weather depend on the temperature and other factors

(1) Wind Chill – when it is cold, wind will cause our bodies to lose heat faster. The effect is quantified by the ‘wind chill factor’ (see your text for specifics).

(2) Heat Index – when it is hot, high humidity inhibits our bodies’ ability to give off excess heat to our surroundings. The effect is quantified by the heat index. See your text for details.

(3) Other factors – there are numerous other factors that contribute to how hot or cold we feel, including clothing, exposure to water, and more.

4. **Important websites and organizations**

a. [www.weather.gov](http://www.weather.gov) (National Weather Service)

b. [www.noaa.gov](http://www.noaa.gov) (National Oceanographic and Atmospheric Administration)

c. [www.wrh.noaa.gov/slc](http://www.wrh.noaa.gov/slc) (local office of the NWS)

d. [www.nhc.noaa.gov](http://www.nhc.noaa.gov) (National Hurricane Center).

5. **Moisture and atmospheric stability (Chapter 4)**

a. The hydrologic cycle. This is an important general concept, because the movement of water between the air, oceans, snow, ice, rivers and lakes is a key component of weather

b. States of matter –

i) Solid – coolest temperatures, closest packing of atoms/molecules for most substances (but not water), least movement of atoms/molecules, rigid arrangement of atoms/molecules (crystalline), etc.

ii) Liquid – warmer than solid state; close packing but not as close as solids (but water has closer packing than ice), more movement of atoms/molecules, conforms to shape of container it's put in, etc.
iii) vapor. higher temps, atoms/molecules are widely spaced and move very rapidly, virtually no bonding between molecules, easily compressed, etc.

c. heat capacity – know what this is, what the heat capacity is for water (i.e., a number), etc.
d. latent heat – know what this is, how big it is for melting (or fusion) and vaporization (or condensation) for water. this is a critical concept to weather.
e. You should be familiar with the concepts of vapor pressure, water vapor in the air and saturation.
f. Humidity – know about the following things, and be able to apply the ideas:
   i) absolute humidity
   ii) mixing ratio
   iii) saturation mixing ratio
   iv) relative humidity
   v) You should know what the above ideas are (i.e., be able to define them), know how they relate to each other, how they relate to temperature, how they change with temperature, what other factors can cause them to change, etc. You should be able to do simple calculations of relative humidity. You should know how humidity relates to the way the air feels and affects your body.
g. Dew point. know what it is, how it relates to humidity and temperature, how it is often used instead of mixing ratio to describe the water vapor content of air, etc.

STUDY QUESTIONS

If you want to turn these in for insurance, please be sure to neatly answer them in complete sentences on separate sheets of paper and staple everything together! Note that if you score below C- on the exam you can receive points equivalent to a C- by doing these questions AND the suggested problems from the back of the appropriate chapters AND turning them all in before the end of the testing period. The suggested chapter and web problems are listed on the course syllabus.

1. What is a scientific hypothesis?
2. How does a scientific hypothesis become a theory?
3. What is weather? In other words, what characteristics of the atmosphere constitute current weather conditions?
4. How does climate differ from weather?
5. What gasses make up the atmosphere, and what are their abundances (for the four most abundant gasses, give the percentage of the atmosphere that each makes up)?
6. Sketch and label the major thermal layers of the atmosphere, including the approximate heights of the boundaries between the layers.
7. How does temperature change with altitude in the troposphere? Give a number for the typical change in temperature for every 1000 feet more elevation (answer is in Chapter 3).
8. Explain why the base of the troposphere hotter than the top.
9. In what way does temperature change with altitude in the stratosphere?
10. Explain, using complete sentences and a sketch (or two) why high latitudes are cooler than lower latitudes.
11. What is the maximum (noontime) sun angle in Utah on the first day of summer and the first day of winter.
12. Explain, using complete sentences and a sketch, what the solstices (winter and summer) and equinoxes (spring and fall) are and give their approximate dates. Your sketch should include the tilt of the Earth’s spin axis relative to the plane of the ecliptic.
13. What are the significance of the Tropics of Cancer and Capricorn, in terms of the seasons (i.e., sun angle), and where are they located?
14. Explain why Utah is colder in the winter than the summer (there are two major reasons).
15. What is electromagnetic radiation? Give some examples of types of electromagnetic radiation. What is visible light, what physical property of it gives rise to the different primary colors?
16. Explain how the amount and type of radiation emitted by a substance varies with the temperature of the substance.
17. Using a sketch and words, explain what the greenhouse effect is. Be sure to fully explain the phenomenon, including the transparency of the atmosphere to radiation generated by the Sun and Earth, and the gasses in the atmosphere that are most important to the effect.
18. Explain what global warming is, and human impact on it. Be sure to relate global warming to the greenhouse effect.
19. What is scattering of radiation? Describe the amounts of scattering of the different wavelengths of light by the atmosphere.
20. Why is the daytime sky blue, the sun yellowish and sunsets red?
21. Explain what albedo is, and give some examples of values of albedo for common substances.
22. Explain the balance of energy from incoming and outgoing radiation at high and low latitudes. Your explanation should include the disparities between the amount energy that arrives vs. leaves back into space at both high and low latitudes.
23. Briefly describe the three temperature scales that we discussed in class; include the freezing and boiling points of water for all three scales.
24. Convert 27°C to Fahrenheit.
25. Explain what temperature is.
26. Explain what heat is.
27. Describe three ways that heat can be transferred.
28. When a meteorologist states that the temperature outside is 35°F, what specifically is he or she referring to, and how would that value have been measured? (note that this question is asking about temperatures of different substances, sun vs. shade, etc.)
29. What is usually the hottest time of day, and why? What is usually the coldest time of the day (24 hr day), and why?
30. Is the annual temperature range usually greater in the tropics or the poles? Why?
31. Compare the temperature of a cloudless day to an overcast day (24 hr day), assuming all else is equal (time of year, etc.). Be sure to compare the high temperature, the low temperature and the mean temperature for both cases. Explain why clouds have the large effects on temperature that you have described.
32. Explain the effect of large water body (e.g., the ocean) on a city. Include average wind direction in your explanation.
33. How does water’s heat capacity impact the weather of coastal areas?
34. What are the 6 main factors that control the temperature at a location.
35. New York and Seattle both are on coastlines, yet Seattle’s weather is much more influenced by its nearby ocean. Why is Seattle more affected by the ocean, and what are the effects of the ocean on Seattle?
36. At what time of day do minimum temperatures usually occur? Why?
37. Explain what the environmental lapse rate is.
38. Explain what a temperature inversion is.
39. Explain what heat capacity is. How does the heat capacity of water compare to other natural substances?
40. What are the three states of matter that we discussed in class? Write down the three states of matter, and using arrows show how matter can change back and forth between the different states. Label the arrows with the names of the transitions (as discussed in class).
41. Give numerical values to the following for water: freezing point, melting point, and boiling point (all for sea level).
42. How does a gas differ from a liquid?
43. When you see whitish steam above a pot of water on the stove, are you seeing water in the liquid or vapor state?
44. Explain what latent heat is.
45. What are the latent heats of freezing and condensation for water (give a number!).
46. Explain what humidity is, and what is different about the air when the humidity is higher.
47. Explain what is meant by the phrase “the air is saturated.”
48. What is mixing ratio? How is it recorded (what are the units), and what is its use? How does it differ from, and what are its advantages relative to absolute humidity?
49. What is saturation mixing ratio? How does it vary with temperature?
50. What is relative humidity? Define it thoroughly; be sure to define it in terms of mixing ratio and saturation mixing ratio.
51. Compare the humidity (relative and mixing ratio) of 17°F air during foggy weather in the winter to 98°F air at 4 pm in July.