

Geography 304: PHYSICAL METEOROLOGY AND CLIMATOLOGY
Fall 2002
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FINAL EXAMINATION

Total marks available: 40

This exam has 12 pages. Please check they are all present.

Name: _____

Instructions

Format of the exam:

- # Part A: 12 multiple choice questions (1 mark each)
- # Part B: 6 short answer questions (2 marks each)
- # Part C: 2 long answer questions (8 marks each)
- # Total marks: 40.

Answer all of the questions in Part A and B and two of the four from Part C.

Useful information and constants:

Equations		
Hypsometric equation	$P = P_0 e^{-(a/T)*z}$	T = temperature in K a = constant (0.0342 K/m) z = height (m) P ₀ = pressure at sea level (mb or kPa) P = pressure at height z (mb or kPa)
Stefan-Boltzmann Law	$F = \epsilon \cdot \sigma \cdot T^4$	F = maximum rate of radiation emitted by an object (W m ⁻²) ε = emissivity (0-1) σ = Stefan-Boltzmann constant (5.67*10 ⁻⁸ W m ⁻² K ⁻⁴) T = objects surface temperature (K)
Inverse-square law	$F_2 = F_1 \cdot \left(\frac{R_1}{R_2} \right)^2$	r ₁ and r ₂ = two distance from Sun F ₁ and F ₂ are fluxes at those distances.
Energy balance model	$T = \sqrt[4]{\frac{S(1-\alpha)}{4\epsilon\sigma}}$	S = solar constant (W m ⁻²) α = albedo ε = emissivity σ = Stefan-Boltzmanns constant = 5.67 *10 ⁻⁸ K ⁻⁴ W m ⁻² T = surface temperature (K)
Wien's law	$\lambda_{\max} = \frac{2898}{T}$	T = surface temperature (K) λ _{max} = wavelength of maximum radiative flux (μm)
Critical radius for CCN activation	$R^* = \sqrt{\frac{c_3 * i * m_s * T}{M_s}}$	T=absolute temperature (K) i=number of ions per molecule in solution (van't Hoff factor) m _s = mass of solute in droplet (g) M _s = molecular weight of solute c ₃ =3.868*10 ¹³ μm ² K ⁻¹ g ⁻¹
Critical super saturation (S*) for CCN activation	$S^* = \sqrt{\frac{c_4 * M_s}{i * m_s * T^3}}$	T=absolute temperature (K) i=number of ions per molecule in solution (van't Hoff factor) m _s = mass of solute in droplet (g) M _s = molecular weight of solute c ₄ =1.278*10 ⁻¹⁵ K ³ g ⁻¹
Geostrophic wind calculation for use on a surface chart	$V_g = -\frac{1}{2\omega \sin \phi \rho} \frac{dP}{dn}$	ω = angular velocity of spin (Earth = 7.29*10 ⁻⁵ s ⁻¹). V _g = velocity (geostrophic wind speed) φ = latitude. ρ = air density <i>Recall: 1 mb = 100 Pa. 1 km = 1000 m</i>
Geostrophic wind calculation for use with upper level charts	$V_g = -\frac{g}{2\omega \sin \phi} \frac{dz}{dn}$	ω = angular velocity of spin (Earth = 7.29*10 ⁻⁵ s ⁻¹). V _g = velocity (geostrophic wind speed) φ = latitude. g = gravity (9.8 m s ⁻²)
Other information		
Dry adiabatic lapse rate	DALR = 10 °C/km	
Saturated adiabatic lapse rate	SALR = 3-9 °C/km	
Temperature conversions	To convert temperatures in Celsius to Fahrenheit: T in F = 9/5.*T in C + 32 To convert temperatures in Fahrenheit to Celsius: T in C = 5/9*(T in F - 32) To convert from Celsius to Kelvin: Add 273.15	

Part A: Mark your answer by circling the letter of the correct answer.

1 mark each

1. The saturated adiabatic lapse rate:
 - a) Is a constant
 - b) Depends on the ascent rate of the air parcel
 - c) Varies with latitude
 - d) Depends on the water vapor content of the air parcel
 - e) Varies according to the temperature of the air parcel

2. In an unstable atmosphere an air parcel is forced to rise from the ground to 200 m above the ground, then the force that made it rise is removed. What happens?
 - a) A cloud starts to form.
 - b) The air parcel continues to rise
 - c) The air parcel remains at 200 m
 - d) The air sinks
 - e) The air parcel becomes potentially unstable

3. The principal reason that urban areas are typically warmer than the surrounding rural areas:
 - a) Net radiation is lower in urban areas
 - b) Urban areas are heat sinks
 - c) Urban areas are drier
 - d) Rural areas have higher albedo
 - e) Urban areas are wetter

4. Ana-regions on cold fronts are the most vigorous portions of the front they are characterized by:
 - a) Jet streaks
 - b) Uplift of warm air
 - c) Uplift of cold air
 - d) Latent heat release
 - e) None of the above

5. Highest wind speeds are typical observed in which area of a hurricane:
 - a) The eye
 - b) Right rear quadrant
 - c) Right front quadrant
 - d) Left rear quadrant
 - e) Left front quadrant

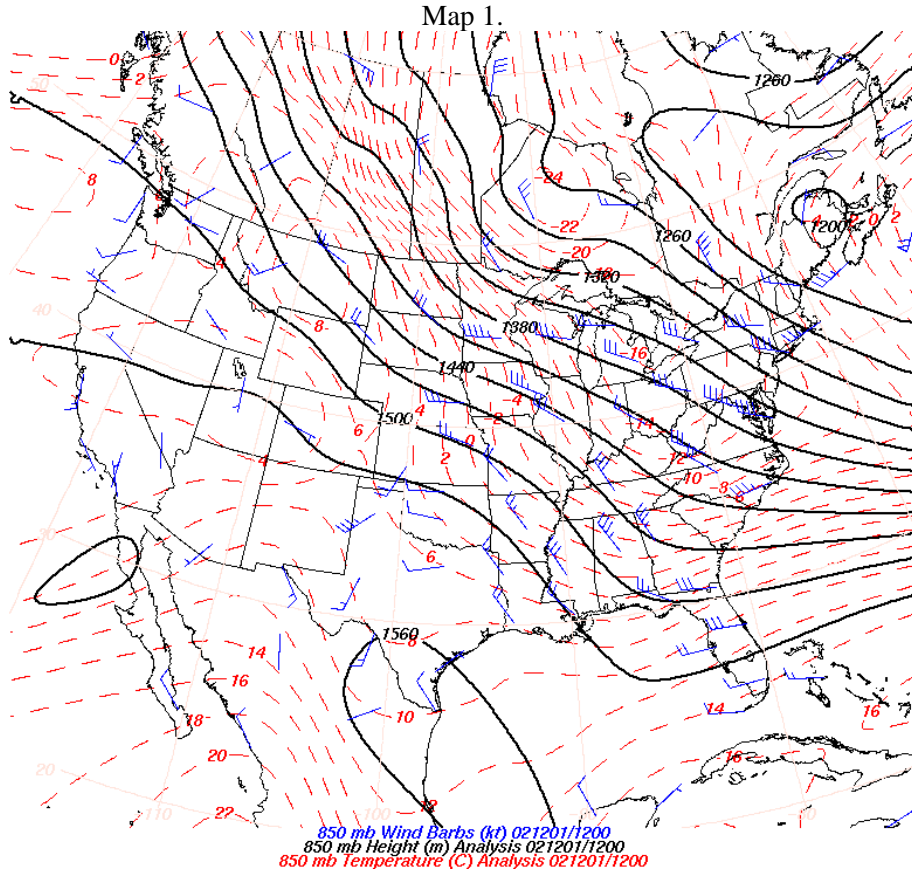
6. The environmental setting where a hurricane is most likely to develop:
 - a) The geographic equator
 - b) Where sea surface temperatures are $> 27^{\circ}\text{C}$
 - c) Where sea surface temperatures are $< 27^{\circ}\text{C}$
 - d) In regions of strong vertical wind sheer
 - e) In the mid-latitudes

7. Of the forces that act upon an air parcel, the one that causes the air parcel to move is:
 - a) Pressure gradient force
 - b) Centrifugal force
 - c) Coriolis force
 - d) Friction
 - e) None of these

8. If the lifted index ($T_{a500} - T_{1500}$) is large and positive what would you forecast?
- Thunderstorm development
 - Tornadoes
 - Tropical cyclones
 - Tornado
 - No severe weather
9. You are examining a skew T log p diagram from a balloon ascent from a remote airport within the last 30 minutes and notice that the dry bulb temperature and dew point temperature are within 2°C of each other between 870 and 940 mb but the lifting condensation level is 600 mb, a pilot calls to ask if there is low level cloud present at the site. You reply:
- There is 1/10 low cloud cover
 - Yes
 - No but there will be soon
 - No and no cloud is likely to develop
 - No the cloud base is at 600 mb
10. The Coriolis force:
- Is maximum at the equator
 - Is a cause of the geostrophic wind
 - Would increase if the spin rate of the Earth increased
 - Is variable with the season
 - Is caused by high pressure gradients
11. The cause of stratospheric ozone depletion that results in an ozone hole of the polar regions is:
- Homogeneous (gas phase) chemical reactions
 - Reactions with the oxygen molecule
 - Transport of ozone depleted air from the troposphere
 - Heterogeneous (surface) chemical reactions
 - Reaction of ozone with carbon dioxide
12. The polar jet stream marks the location of:
- Minimum temperature contrast
 - The tropopause
 - Maximum temperature contrast
 - Outflow from cumulo-nimbus clouds
 - The Rossby waves

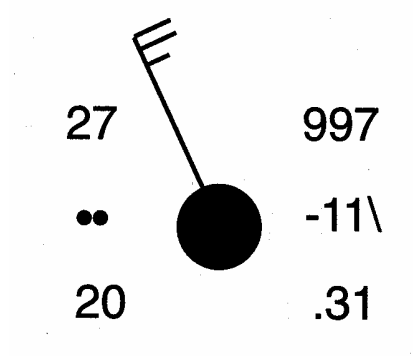
Part B: Write your answers in the space provided.
2 marks each

1. a. Based on the 850 mb chart shown below is cold or warm air advection occurring in Illinois? (1 mark)
- b. Thermal advection is one mechanism for cyclogenesis, name and describe one other. (1 mark)



3. Explain how sun spots affect the mean temperature of the Earth (2 marks)

4. Decode the station model given below (there are 10 parameters, you need to decode any 4): (2 marks)



5. Imagine an air parcel in the Ohio River valley where the CCN are made of $(\text{NH}_4)_2\text{SO}_4$ - Will a droplet of $(\text{NH}_4)_2\text{SO}_4$ solution (i.e. $i = 3$, $M_s = 132.13$) grow if: $T = 284 \text{ K}$, $m_s = 2 \times 10^{-15} \text{ g}$, $R = 0.5 \text{ }\mu\text{m}$? (2 marks)

6. Describe the environmental conditions that are used to make seasonal forecasts of hurricane activity in the Atlantic. (2 marks)

Part C: Mark your answers below the question.

8 marks each

Answer 2 of 4 questions

1. In the Sierra Nevada you climb Clingmans Dome (2013 m). As you climb you notice the temperature decreases, you also notice that as you climb it gets harder and harder to breath.

- a) If the pressure at the bottom is 1013 mb and the temperature is 278 K, what is the atmospheric pressure at the top of Clingmans Dome? (2 marks)
- b) Why might the answer you gave to a) be wrong? (2 marks)
- c) If the dew point temperature at the base of Clingmans dome is 261 K is the top of Clingmans Dome cloud free? (2 mark)
- d) If, on average, oxygen comprises 20 % of the Earths atmosphere, and atmospheric density at the sea level is 1.25 kg m^{-3} if you breath 1 m^3 of air at the summit and your lungs are perfectly efficient at removing oxygen how much less oxygen will you actually absorb than if you breathed 1 m^3 at the base of the Dome? (2 marks)

2. Imagine a solar system where the central star has a surface temperature of $8055\text{ }^{\circ}\text{C}$, an emissivity of 0.9 and a radius of $5.5 \times 10^6\text{ km}$ with a planet that orbits at a distance of $6.1 \times 10^9\text{ km}$. Answer the following:

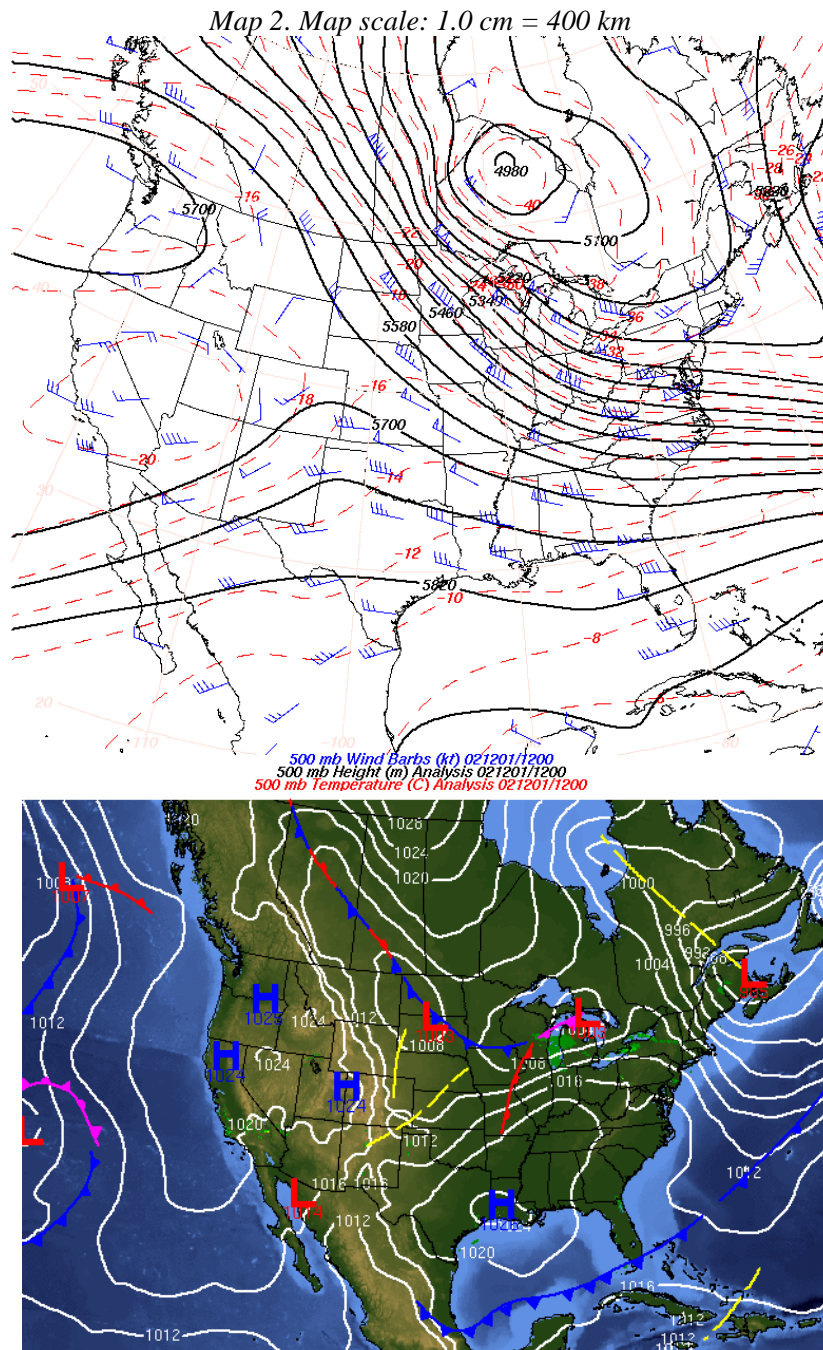
- a) Is the star a black body? (1 mark)
- b) What is the radiative flux from the surface of the star in W m^{-2} ? (1 mark)
- c) Assuming that humans can only exist on a planet which has a surface temperature of -10 to $40\text{ }^{\circ}\text{C}$, could humans inhabit this planet assuming it has an albedo of 0.1 and an emissivity of 0.4? (4 marks)
- d) Based on the information provided describe the atmospheric and surface conditions of the planet (2 marks)

3. Map 2 shows a 500 mb chart.

a) For the conditions shown on Map 3 calculate the geostrophic wind speed over central Illinois. (4 marks)

b) Compare your answer with the measurement shown over Illinois. (1 marks)

c) The surface map below the 500 mb chart is taken for the same time period. Based on the 500 mb chart and the surface chart forecast the movement of the low pressure over the Great Lakes and make a forecast for Indiana for the next 24 hours. (3 marks)



4. Severe weather

- a) What scale is used to quantify the magnitude of tornadoes? (1 mark)
- b) Describe what the scale is based on. (1 mark)
- c) Describe one of the limitations of this scale. (1 mark)
- d) What is the origin of the rotation that eventually forms the tornado? (1 mark)
- e) Most tornadoes in Indiana are associated with thunderstorms which are in turn associated with cold fronts. What are the environmental conditions that favor thunderstorm development? (4 marks)