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SIO 217a Atmospheric and Climate Sciences I: Atmospheric Thermodynamics

Fall 2013 Final Exam (No calculators, notes, books, PDAs.)

Curry and Webster, Ch. 1-8, 12, 13

No calculators or other devices are allowed. Write all calculations explicitly in terms of numbers, but you do not need to evaluate the exact numerical answer.

Here are some numerical values, some of which may be useful on this exam:
Average radius of Earth: 6370 km
Mean reflectivity of the Earth: 0.31
Mean molecular weight of dry air: 29 g/mole
Mean molecular weight of water vapor: 18 g/mole
Gas constant for dry air, $\boldsymbol{R_d}$: 287 J deg^{-1} kg^{-1}
Gas constant for water vapor, $\boldsymbol{R_v}$: 461 J deg^{-1} kg^{-1}
Specific heat at constant pressure, $\boldsymbol{c_p}$: 1004 J deg^{-1} kg^{-1}
Specific heat at constant volume, $\boldsymbol{c_v}$: 717 J deg^{-1} kg^{-1}
Latent heat of vaporization for water at 273K, $\boldsymbol{L_{lv}}$: 2.5×10^{6} J kg^{-1}
Solar luminosity: 3.92×10^{26} W
Earth-sun distance: 1.50×10^{11} m
Stefan-Boltzmann constant, $\boldsymbol{\sigma}$: 5.67×10^{-8} W m^{-2} K^{-4}

1. **Köhler/Clouds/Stability Question (20 pts):** Warm clouds are typically found in the lower troposphere and contain droplets of liquid water.
   a. What causes a cloud to form?
   b. What role do aerosol particles play in cloud formation?
   c. If the parcel rises in cloud adiabatically, what is the lapse rate for the parcel in the cloud?
   d. Sketch and state how you would derive the lapse rate in part (c).
   e. What quantity describes the potential energy that is available for convection in the cloud?

2. **Definitions Question (15 pts):** Define the following terms in 10 words or less; an equation, graph, or sketch may be added if appropriate:
   a. optical depth
   b. absorptivity
   c. hydrostatic balance
   d. conditionally stable
   e. isentropic

3. **Term Project Question (10 pts)**: Answer TWO of the following questions; be brief, but include graphs, sketches, or key variables in your answer.
   a) What controls the growth of droplets after activation in cloud?
   b) How do volcanic eruptions affect the quantity and distribution of solar insolation?
   c) How is extinction related to the size of cloud droplets?
   d) How does the entrainment of dry air affect the lapse rate of a saturate parcel?

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4. **First/Second Laws Question (15 pts):** In a saturated air parcel, the temperature changes are often largely due to the condensation of water. State the assumptions of your approach.
   a) Write the first law of thermodynamics, assuming a reversible process with no volume change.
   b) Show how (a) can be used to calculate the change in temperature resulting from the condensation of water in cloud.
   c) State the assumptions that you made in the calculation in (b).

5. **Clausius Clapeyron Question (20 pts):** A local company has proposed to produce freshwater from the water vapor in ambient air at Point Loma. Assume the air at their Point Loma site is 30°C and 100% RH. The saturation vapor pressure (of water) at a temperature of 30°C is 42 hPa. Then they cool the air using passive geothermal cooling to 10°C. (Assume that no water actually freezes, so that you remain just above freezing throughout.) State how you would find the values below <u>from the information provided in this exam</u> for the air (after this cooling), including any laws, equations, and assumptions used, and simplifying as much as possible:
   a. saturation vapor pressure (of water) at 10°C.
   b. specific humidity.
   c. mixing ratio.
   d. virtual temperature.
   e. the amount of water expected to condense to liquid for each kg of air cooled.

6. **Climate Forcing and Feedback Question (20 pts)**
   a. Define climate forcing and give an example of a man-made forcing in the current decade.
   b. What is the difference between a positive and negative feedback?
   c. Give an example of a positive feedback in the Earth system and describe the physical processes involved.
   d. Does the simple climate model studied in class include forcings, feedbacks, or both? Explain what is and isn't included and why.
   e. Why do different global climate models get different temperature changes for the same forcing (e.g. for $2xCO_2$)?