SIO 217A Question CS General Exam 2006

The following items are NOT allowed in this exam: notes, books, readings, computers and related technologies (PDAs, calculators, blackberries, cell phones). Please leave these items (e.g. in your backpack) with the proctor when you pick up your exam.
For problems involving calculation, it is OK to give an answer in the form of a simple arithmetic expression, without obtaining the final numerical answer. For example, if you are asked what is the area of the Earth, it is OK to say the answer is $4 \times 3.1416 \times (6370)^2$ km^2 and leave it in that form.

Here are some numerical values, some of which may be useful on this exam:
Average radius of Earth: 6370 km
Mean molecular weight of dry air: 29 g/mole
Mean molecular weight of water vapor: 18 g/mole
Gas constant for dry air: 287 J deg^{-1} kg^{-1}
Gas constant for water vapor: 461 J deg^{-1} kg^{-1}
Specific heat at constant pressure: 1004 J deg^{-1} kg^{-1}
Specific heat at constant volume: 717 J deg^{-1} kg^{-1}
Earth's albedo 0.31, solar luminosity 3.92×10^{26} W
Earth-sun distance 1.50×10^{11} m
Stefan-Boltzmann constant 5.67×10^{-8} W m^{-2} K^{-4}.

1. Consider a planet with an atmosphere in hydrostatic equilibrium. Assume that the atmosphere is an ideal gas. Also assume that the temperature is a maximum at the surface of the planet, and, as height increases, the temperature in the atmosphere decreases linearly (in other words, temperature decreases with height at a constant rate). Derive a formula for atmospheric density as a function of height in this atmosphere.
2. Now consider the planet Earth itself. Using a diagram with temperature on the horizontal axis and pressure or altitude on the vertical axis, describe the processes involved in the development of a typical cumulus cloud. In your discussion, include the relevance of the lapse rate, the stability of the atmosphere, phase changes of water, and other factors important to cumuliform convection.
3. Now consider a planet that is identical to Earth in all respects except for its cloud cover, which is decreased to α_p=0.28 from the standard value of Earth's albedo. State and simplify the equations needed to determine the equivalent black-body emission temperature of this planet if. State all assumptions and approximations. Do you expect that this planet will be hotter than the Earth or colder? Discuss the reasons.