EARTH AND SPACE SCIENCE	**Autumn 2017**
431 *PRINCIPLES OF GLACIOLOGY*	4 Credits, SLN 14841
505 *THE CRYOSPHERE*	4 Credits, SLN 14862

Lab Week 3 – Vapor Pressure and Supercooling

PART 1: Vapor Pressure Calculations

1) The atmosphere exerts a pressure on the material sitting within it. While we often think of that pressure as a single value, we can also think of it in terms of "partial pressures" – the effective pressure contribution of each of the different component gasses that make up the atmosphere. When the partial pressure of water vapor in the atmosphere is less than the saturation vapor pressure of solid/liquid at Earth's surface, more molecules will leave the solid/liquid phase than those that enter it from the gas, leading to net sublimation/evaporation.

a) Given the following equation for partial pressure, compute the partial pressures for each of the major gasses that make up the atmosphere:

$$P_p = f_m * P_{Tot}$$

Where P_p is the partial pressure of the constituent gas, f_m is the mole fraction of that gas in the mixture, and P_{Tot} is the mixtures total pressure.

Nitrogen mole fraction – 78%
Oxygen mole fraction – 21%
Argon mole fraction – 0.9%

b) Relative humidity is the measure of the partial pressure of water vapor in the atmosphere, relative to the saturation vapor pressure of water at that temperature. The August-Roche-Magnus approximation provides the saturation vapor pressure of water as a function of temperature:

$$e_s = 610.94\, exp\left(\frac{17.625 * T}{T + 243.04}\right)$$

(where e_s is vapor pressure in Pa, and T is temperature in °C)

What is the mole fraction of water in the atmosphere at 100% humidity at 10°C, 20°C, 30°C, and 40°C?

c) The magnitude of the vapor pressure gradient can be used to determine the rate of sublimation/evaporation. Rank the following conditions from most sublimation/evaporation to least (show the computed vapor pressure gradient between the fluid and the air).

i	Temp – 15 °C	Relative Humidity - 50%	
ii	Temp – 10 °C	Relative Humidity - 10%	
iii	Temp – 30 °C	Relative Humidity - 80%	

iv	Temp – 20 °C	Relative Humidity - 40%	
v	Temp – 35 °C	Relative Humidity - 90%	
vi	Temp – 20 °C	Relative Humidity - 50%	

2) Draw the geometry of a snow crystal forming in the presence of undersaturated air at -15C and in the presence of supersaturated air at -15C, and explain why they take on those shapes. Which of these two snowflakes will undergo more dramatic metamorphism once it is in an isothermal snowpack, and why?

3) Lake Vostok is a subglacial lake in East Antarctica. The average surface temperature over Lake Vostok is -55°C, and the geothermal flux (the heat flux into the base of the ice sheet) is 44 mW/m^2. Solve for the minimum ice thickness over lake Vostok that allows for an ice-bottom temperature that is at the melting point. *(Hint – there are two things that vary here as a function of ice thickness: the ice-bottom temperature and the ice-bottom melting point)*

PART 2: Supercooled Water

We will visit the freezer in the ISOLab up on the 3rd floor, where several bottles of SMART Water were placed yesterday.

- What is the temperature in the freezer?
- Why did we empty out some of the water before starting the experiment?
- What are the observed states of the water in the various bottles?
- What happened when we handled the liquid bottle, and why?
- Why is SMART Water a good medium for this supercooling demonstration? (You can read the label.)
- Speculate on what might have been different between the two bottles.
- Calculate the amount of energy required to bring the water back to 0°C. How does this compare to the amount of energy required to freeze the entire volume?
- With the knowledge that freezing releases heat energy, calculate the fraction of the water that turned into ice.
- Water cannot supercool below -40°C. With that in mind, is it ever possible for a volume of supercooled water to freeze entirely? Why or why not?