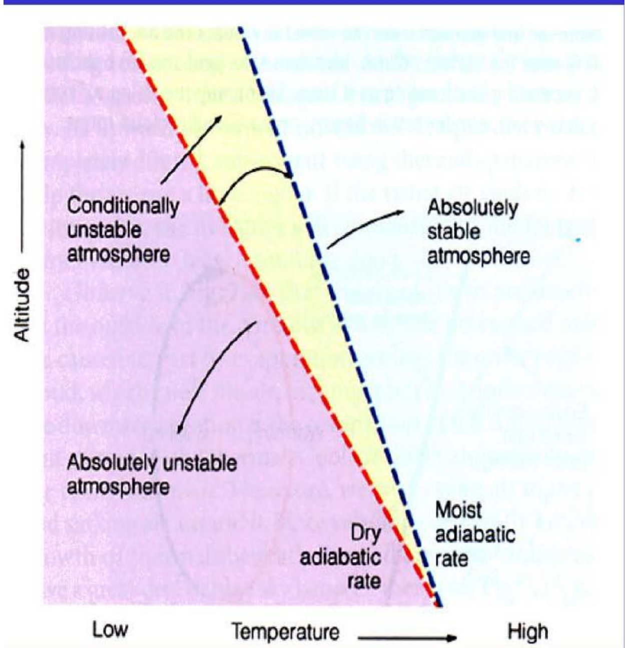
ATMO551A: Physical Meteo. I. 20 questions for Ph.D qualify exam (Provided by Dr. Xiquan Dong)

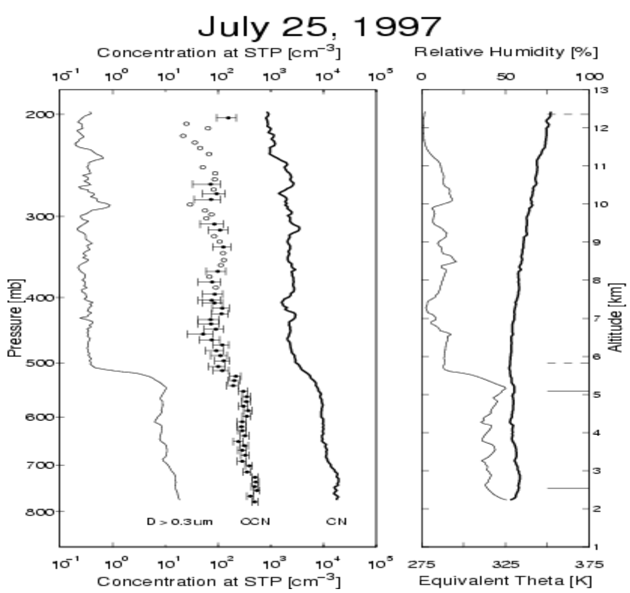
1). (a) What are moist and dry adiabatic lapse rates?

(b) Explain physically absolutely stable and unstable, and conditional unstable atmosphere from the following plot? (You may draw a line to explain)



2) a) Briefly explain each of the 3 growth processes for ice crystals.

b) Which process (or processes) can produce precipitation sized rain drops. Explain the physical reasoning behind why this process (or processes) can produce raindrops.



3) The balloon ascent profiles include the smallest size channel of the optical particle counter (D>0.3 mm, thin line), the CCN concentration (1% supersaturation, circles), and the CN concentration (D>0.01 mm, thick line). Based on this plot to answer the following questions:

(a) Why are these three concentrations different?

(b) Where the aerosol concentrations suddenly drop and why?

© Why there are no aerosols below 800 mb?

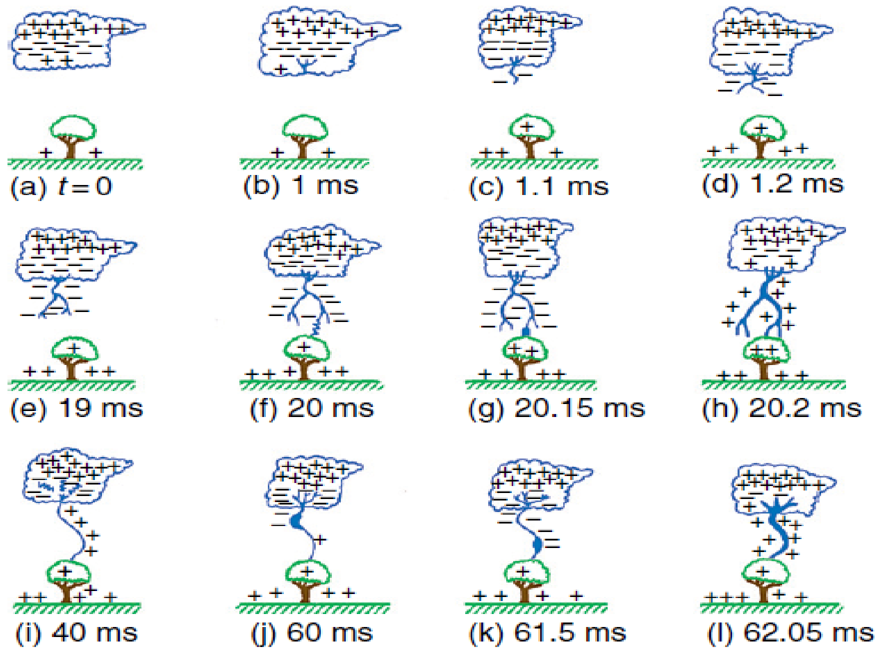


Fig. 6.53 Schematics (not drawn to scale) to illustrate some of the processes leading to a ground flash that charges the ground negatively. (a) cloud charge distribution, (b) preliminary breakdown, (c–e) stepped leader, (f) attachment process, (g and h) first return stroke, (i) K and J processes, (j and k) the dart leader, and (1) the second return stroke. [Adapted from M. Uman, *The Lightning Discharge*, Academic Press, Inc., New York, 1987, p. 12, Copyright 1987, with permission from Elsevier.]

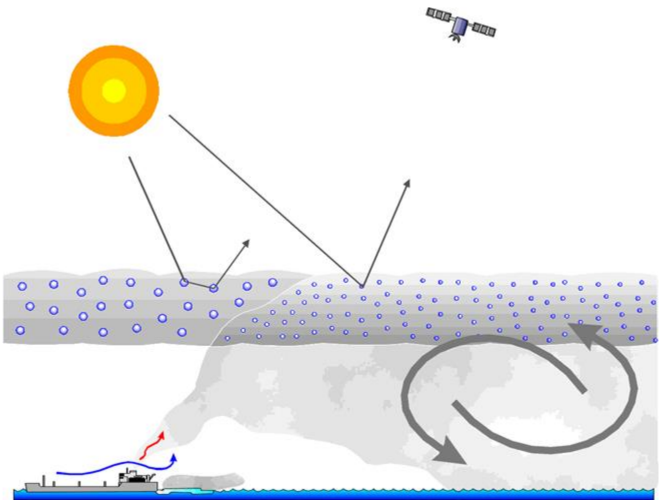
4) The above diagrams illustrate the formation of lightning process. Describe each step from (a)-(l).

5) (a) Discuss the temperature-pressure related hydrostatic balance over the Tropic, middle latitudes, and Arctic regions. (b) If an air parcel is under the hydrostatic balance in the tropic regions, we suddenly move it to Arctic regions, what will be happened? (c) Discuss the physical reasons for having more weather events occurred in middle latitudes, not in Arctic and tropical regions?

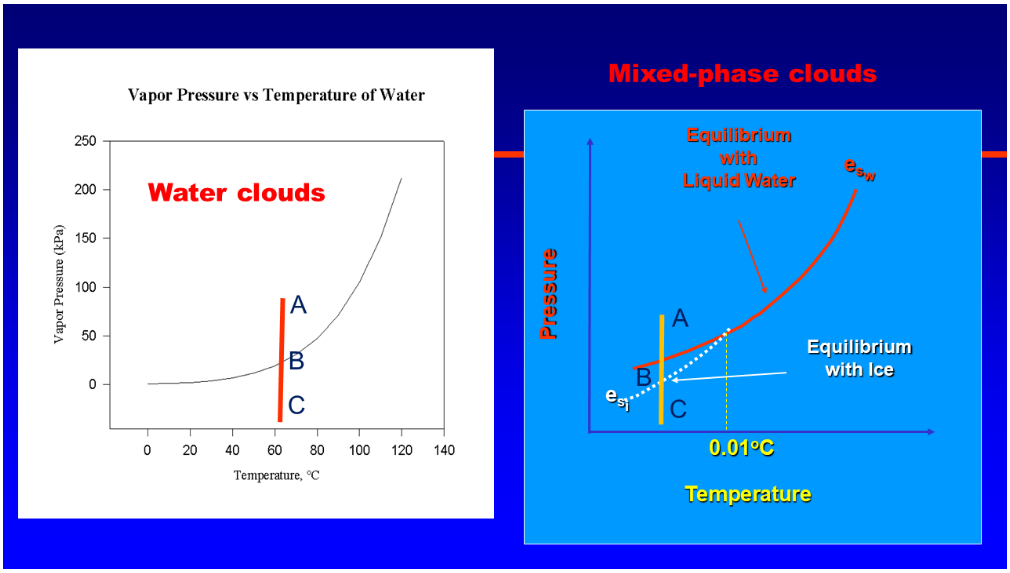
6) Compared with other planets, the earth stratopause's (at 50 km altitude) temperature is much higher, (a) discuss the physical reasons? (b) Studies have shown that the ozone concentration peaks at around 25 km, not at 50 km, explain why the max temperature of earth stratosphere does not occur at 25 km altitude. © Discuss the possible effects if this ozone layer were disappeared.

7) In the class, we have explained the D, E, F layers of Ionosphere during day and night and what frequencies we should use for three stations nearby Tucson (such as Phoenix), a little away Denver, and far away New York City (Explain physically)
Now suddenly we have Solar Flares which increase in X-ray radiation. Discuss what are the impacts of the Solar flares to the D, E, F layer ionizations and their corresponding radio communication to above three cities (discuss in both day and night).

8). (a) What are aerosol direct and indirect effects (first and second indirect effects)?
(b) Briefly describe the aerosol indirect effects from following plot (What are the similarities and differences of radiation, cloud microphysical properties and lifetime before and after the cargo ship, and explain their causes in-depth?)



9) Based on the following two plots for water clouds (left) and mixed-phase (right) clouds, explain their physical meanings at Points A (above e_{sw}), B (on the line for water clouds, fall between e_{sw} and e_{si} for mixed-phase clouds), C (below e_{sw} for water and e_{si} for mixed-phase cloud). You should explain their saturation status and condensation/evaporation processes in depth.



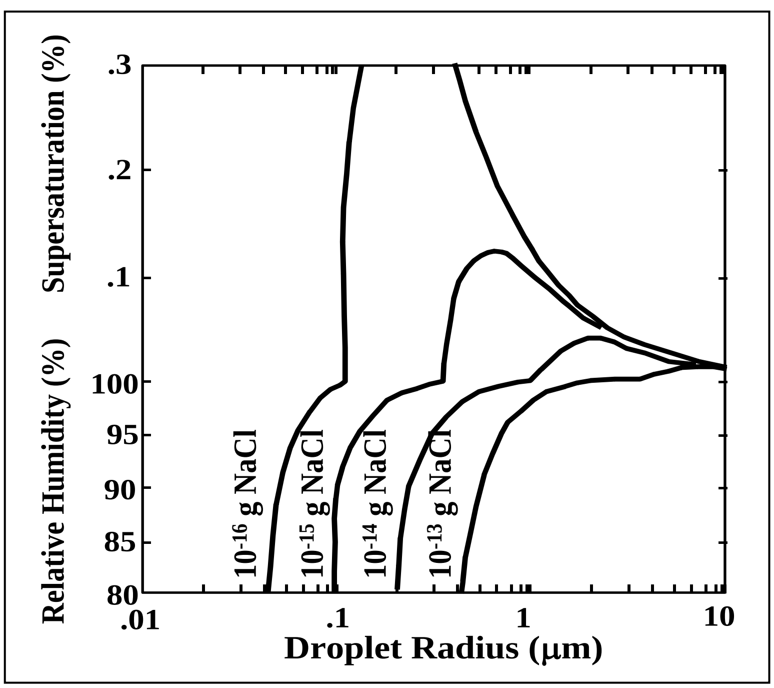
10) On a particular day the orographic cloud on the island of Hawaii is 2.5 km thick with a uniform liquid water content of 0.6 g/m^3. A drop of 0.15 mm radius at cloud top begins to fall through the cloud.
(a) Find the size of the drop as it emerges from cloud base, neglecting vertical air motions in the cloud. In this and subsequent parts of the problem neglect growth by condensation, use elementary form of the continuous growth equation, and assume a collection efficiency unity.

(b) Assuming that the terminal velocity of the drop is equal to $k_3 r$, where $k_3 = 8 \times 10^3\ s^{-1}$, find the time taken by the drop to fall through the cloud.
(c) Hawaiian orographic clouds are actually maintained by gentle upslope motions, which cause a steady, weak updraft. Solve for the size of the drop in part (a) as it emerges from the cloud if there is a uniform updraft of 30 cm/s.

11) A drop of 0.2 mm diameter is inserted in the base of the cumulus cloud that has a uniform liquid water content of 1.5 g/m^3 and a constant updraft of 4 m/s. Using the elementary form of the continuous-growth equation and neglecting growth by condensation, determine the following:
(a) the size of the drop at the top of its trajectory;
(b) the size of the drop as it leaves the cloud;
(c) the time the drop resides in the cloud.

Assume a collection efficiency of unity, and for the dependence of fall velocity on size us the data in Table 8.1. *Note:* at top of cloud, $w = v = k_3 r$, $k_3 = 8*10^3\ s^{-1}$

12) Refer to the following Kohler curve to answer the following questions.
   a. What are the critical radius and critical supersaturation for a 10^{-14}g aerosol composed of NaCl?
   b. What are the critical radius and critical supersaturation for a 10^{-15}g aerosol composed of NaCl?
   c. Brief discuss what happen for a droplet if $r < r_c$ and $r > r_c$
   d. What range of sizes is solute effect most important for a 10^{-15}g aerosol composed of NaCl?
      ________ µm to ________ µm
   e. What range of sizes is Kelvin effect most important for a 10^{-15}g aerosol composed of NaCl?
      ________ µm to ________ µm

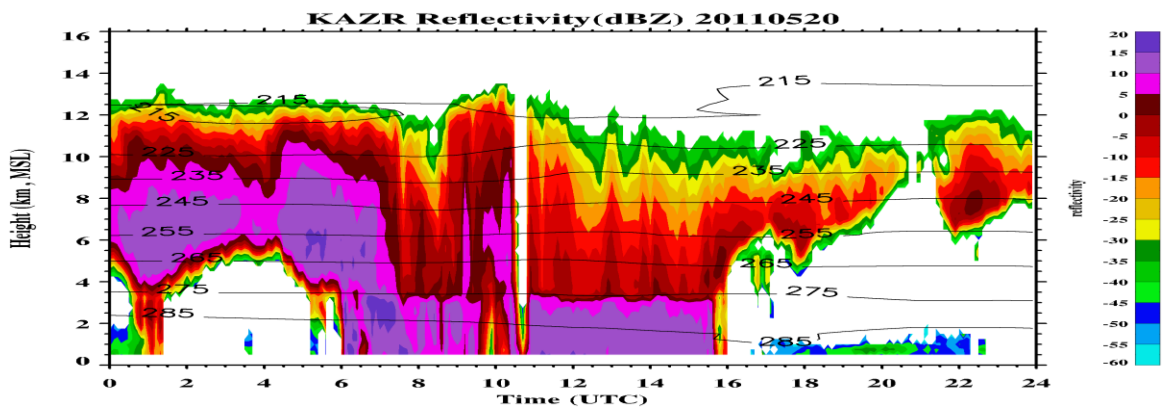


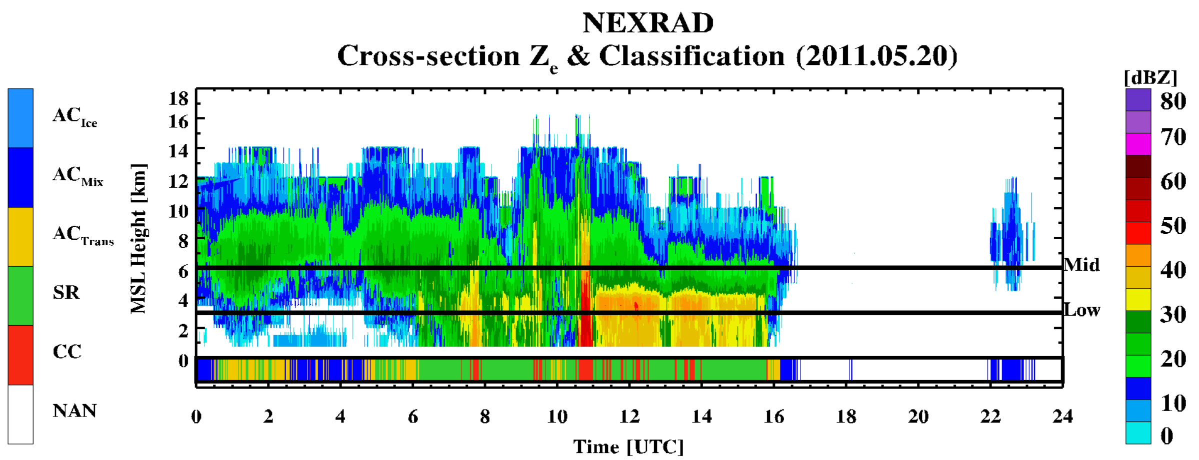
13) The following two images observed by DOE ARM cloud radar (35 GHz, KAZR) and NOAA NEXRAD precipitation radar (3 GHz, NEXRAD). Based on these two radar reflectivity measurements, answer the following questions (for graduate students only, but under graduate students will get extra credit).

(a) Why there is a sudden increase in both radar reflectivity around 4 km? What is this layer called? What are dominant (ice crystals or water droplets) above and below this layer?

(b) Comparing their similarities and differences (find at least 5 similarities and 5 differences) between two radar reflectivity measurements.

(c) Discuss their advantages and disadvantages when we use these two radars to observe deep convective clouds and precipitation.





14) Aerosol effects on Climate

a) What are atmospheric aerosols, including from natural and human activities, respectively?
b) How do aerosols influence the Earth's Climate?
c) What are the impact of Volcano eruption on the Earth's climate?

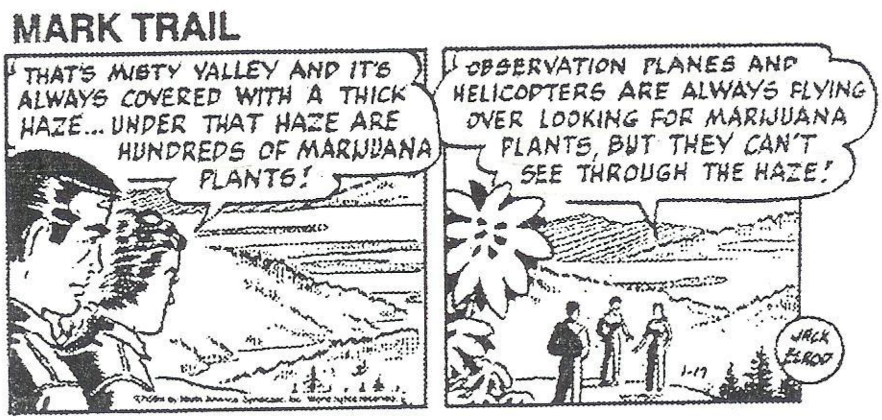
15) Cloud Physics and radiation

Recently in the cartoon strip Mark Trail, statements were made concerning some clever marijuana plant growers, who chose "Misty Valley in which to grow their plants. Because this valley was always covered by haze, spotters in aircraft flying over the valley were not able to see the plants. Misty Valley is thus an ideal place in which to hide the illegal plants. Based on your cloud physics and radiation knowledge, answer the follow questions:

a) Do you think the haze can be formed over a valley for long time? If so, why; if not, why not?
b) Why aircrafts flying over the valley were not able to see the plants (make your assumptions under what cloud optical properties, aircrafts could not see the plants)? Supposing all above

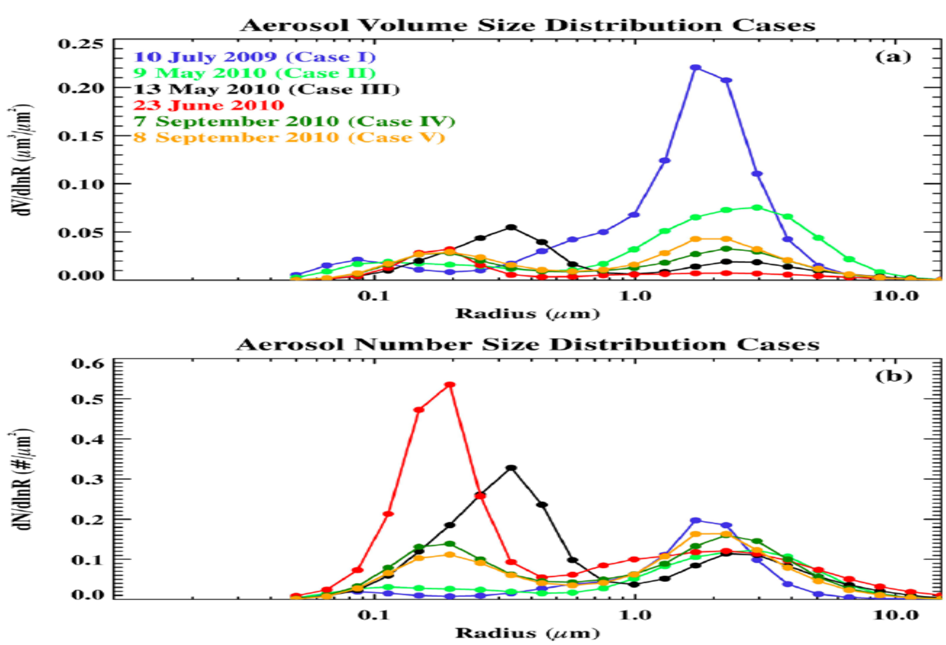
statements are right, list all possible SW and LW fluxes at surface and discuss what fluxes are dominant to the net surface radiation budget?

c) Based on your argument in b), do you think the illegal plants can grow? If so, why; if not, why not?



16) (a) What is the Earth's atmospheric temperature profile (four layers etc) and what is the difference between its temperatures and other planets' temperature profiles?
(b) What are the permanent gases and greenhouse (trace) gases of the Earth Atmosphere? Which one(s) has (have) significant impact on the Earth radiation and temperature?

17) Based on what you learn from ATMO551A, discuss the following two plots (a) dV/dlnR, and (b) dN/dlnR. What can you tell from the aerosol volume and size distributions? And what are their similarities and differences?



18) On the solid line (2), there are two open circles on the left and right sides of the peak. Discuss what happen (particle increases or decreases) if we move the left circle to the left and right sides of the line? So do the right circle?

270 **9 Aerosol and Clouds**

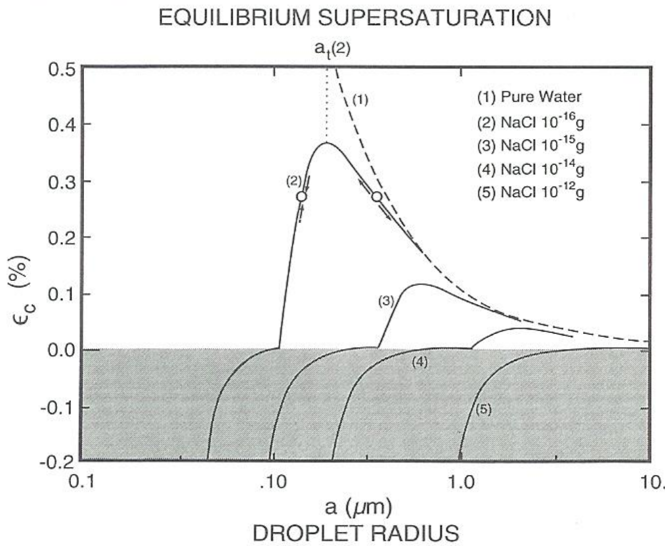


Figure 9.9 Critical supersaturation necessary to sustain a droplet of radius a and containing specified amounts of solute (solid lines). Critical supersaturation for a pure-water droplet (dashed line) is superposed. For a given amount of solute, the corresponding *Köhler curve* describes different forms of equilibrium, depending on whether a is smaller or larger than the threshold radius at the maximum of the curve, a_t. For $a < a_t$, a droplet is in stable equilibrium: Perturbations in a are opposed by condensation and evaporation, which restore the droplet to its original state. For $a > a_t$, a droplet is in unstable equilibrium: Perturbations in a are reinforced, so the droplet either evaporates toward a_t or grows through condensation away from its original state.

19) There are two photos as follows. Explain and discuss physically:
   a) Are they formed in the same method?
   b) What are similarities and differences between two? (At lease 3 similarities and 3 differences)

20) Briefly describe the condensation growth process and adiabatic process? Are the aircraft in situ measured cloud LWC is the same or different to adiabatic process? Particular over the cloud top?

ATMO551B: Physical Meteo. II. 20 questions for Ph.D qualify exam (provided by Drs. Baike Xi and Ave Arellano).

1. Consider the effects of cloud cover on air temperature measured conventionally near the surface.
   a) Discuss the energy balance components and how each is affected by cloud cover.
   b) How would you change your response if instead of clouds you were considering heavy volcanic ash loading of the stratosphere?
   c) In mid-latitudes, the downwelling IR-measured at the group varies by up to 40% between cloudy and clear-sky conditions, even for one day. However, in the deep tropics, the variation is less than 10%, day and night, day after day, even though cloudiness changes substantially. Explain physically the differences in the character of the downwelling IR.

2. A stratus cloud of 200 meters in thickness is composed of uniform droplets with a radius of 10 μm and the droplet number concentration of 100 cm^{-3}.
   a) Compute the approximate optical depth of this cloud at a wavelength of 6.3 μm.
   b) Given that the optical depth of water vapor between 6 and 6.5 μm may be approximated as $\tau_v = \sqrt{k_a u}$, where k_a =specific absorption coefficient=98 cm^2 g^{-1}, and u is the column concentration of water vapor, compute the optical depth if all cloud liquid water is converted to water vapor.
   c) Contrast these two optical depths and give a physical explanation for their difference.

3) We examine the effects of different types of idealized aerosols on the surface temperature T_o of the Earth.
   a) Sulfate aerosols scatter solar radiation (no absorption), and do not absorb or scatter terrestrial radiation. What effect would an increase in sulfate aerosol concentrations have on T_o?
   b) Soot aerosols absorb solar and terrestrial radiation (no scatter). Discuss briefly how the effect of a soot layer on T_o depends on the altitude of the layer.
   c) Desert dust aerosols scatter solar radiation (no absorption) and absorb terrestrial radiation (no scatter). Consider our simple greenhouse model where the gaseous atmosphere consists of a single thin layer that is transparent to solar radiation but absorbs a fraction f of terrestrial radiation. We add to that layer some desert dust so that the planetary albedo increases from A to $A + \varepsilon$, and the absorption efficiency of the atmospheric layer in the terrestrial radiation range increases from f to $f + \varepsilon'$. Assume that $\varepsilon \ll A$ and $\varepsilon' \ll f$ are small increments so that $\varepsilon = dA$ and $\varepsilon' = df$. Show that the net effect of desert dust is to increase T_o, if

$$\frac{\varepsilon'}{\varepsilon} > \frac{F_s}{2\sigma T_o^4} \approx 1.8$$

   and to decrease T_o otherwise. Here F_S is the solar constant and σ is the Stefan-Boltzmann constant.

4) Calculate the Earth System equilibrium temperature (treated the Earth as a blackbody with radius as 6370 km; solar constant =1365 W m^{-2} and planetary albedo=0.3); If all the Arctic Sea ice melt and the surface albedo reduces to 0.2, what will be the Earth System equilibrium temperature? If there is a sudden volcano eruption, which increases the albedo to 0.4, what will be the new equilibrium temperature?

5) Consider a two-layer model for the atmosphere in the infrared region.

   a) Derive an expression of T_o as a function of α_1 and α_2 (absorption efficiencies, where $\alpha_1 > \alpha_2$), A (surface albedo), and F_S (solar constant). Provide explicit descriptions of your assumptions.

b) How does this expression compare to the single-layer model of greenhouse effect? Provide a physical justification for this two-layer model. At what specific case(s) will this two-layer model be more applicable than the single-layer model?

6) A satellite viewing a surface viewing location under cloud-free conditions measure a 12-um radiance of 6.2 W m^{-2} um^{-1} sr^{-1}.
   a) Compute the brightness temperature T_B.
   b) Compute the actual temperature assuming that the atmosphere is completely transparent, and that the surface has an emissivity of 0.9 at this wavelength.
   c) Is the ratio of T_B to the actual temperature equal to the emissivity? Why?

7) Briefly define active and passive remote sensing. Please provide at least one example of an instrument (frequency or wavelength) for both passive and active remote sensing, respectively. Discuss the advantages and disadvantages of remote sensing (at least 3 aspects each).

8) Consider a two-stream radiative transfer model.
   a) Calculate the optical depth at a wavelength of 0.55 um of a 300 m thick water cloud with a droplet concentration of 100 cm^{-3}. Assume the droplets are monodisperse with a radius of $5\mu m$.
   b) If the asymmetry factor=0.8, calculate the reflectivity and transmissivity of this cloud, assuming no reflectivity from the underlying surface and atmosphere.
   c) Is this cloud optically thick? Why or why not?

9) List the names and briefly describe the energy levels constituting the total energy of a molecule. Discuss the relationships between these energy levels. How is the information on these energy levels used in identifying radiative properties of O_2 or N_2, CO_2 and H_2O, and O_3.

10) Using both math (equation) and physical reasoning, explain the following:
   a) What is an atmospheric contrast?
   b) Under a clear sky, why do we only see objects at a finite (limited) distance?
   c) Why can see a light at a very far distance during night but not during daytime?

11) Define and sketch the 11-yr Solar Cycle. Does the maximum sunspot occurrence correlate with the maximum solar radiation during the 11-yr Solar Cycle? Explain your answer.

12) Briefly describe the following scattering regions: Rayleigh, Mie, and Geometric Optics
   a) What are the typical range of values of the size parameter x corresponding to each region?
   b) Discuss their application in meteorological radar observations for detecting clouds and precipitation.
   c) Explain why the green line and red line have different characteristics?

13) One of the geoengineering solutions to global warming proposed in literature is to install a giant solar deflector (diaphanous sheet stretching 2,000 kilometers across) at a point 2.5 million kilometer from Earth in the direction of the sun. The proposed role of this diaphanous sheet is to compensate for the increased emissivity of the atmosphere because of doubled CO_2 abundance. If the increase in the radiative equilibrium temperature of the Earth–Atmosphere system at the surface due to this increased CO_2 is 1.5 K and that the present radiative equilibrium temperature is 288 K, show that amount (in percent) of deflected radiation is 2%.

14) Describe in detail the mechanisms leading to ozone depletion (ozone hole) in the Antarctica (include chemical reactions if necessary). What are the main features of this ozone hole and why are these features important? What are the main differences in the ozone depletion observed over the Antarctica versus over the Arctic?

15) The precipitable water vapor (PWV or TPW) is the total amount of water vapor in a vertical column (per unit area) that extends from the surface to infinity, and the unit for this quantity is the height that the liquid would have if all the vapor in the column were condensed and collected in a vessel with the same cross-sectional area as the column. Given a global average PWV of 2.5 cm, estimate the total mass of water vapor in the atmosphere. Express your answer in kilograms.
(M_{air} = 29 g mol^{-1}, R = 8.31 J mol^{-1} K^{-1}, Earth's Radius=6,400 km)

16) If the composition of dry air at sea level is found to be: N_2:75.5%; O_2: 23.2%; Ar: 1.3% by mass. Calculate the mole fraction and partial pressure of each component when the total pressure is 10^5 Pa (kg m^{-1} s^{-2}). (N_2 = 28 g mol^{-1}; O_2 = 32 g mol^{-1}; Ar = 40 g mol^{-1}; R = 8.31 J mol^{-1} K^{-1}).

17) Consider a cloudless atmosphere and the infrared portion of the electromagnetic spectrum.
   a) Starting from the general RTE, derive expressions for the upwelling and downwelling radiance in a plane parallel atmosphere as functions of transmittance and optical depth. Provide explicit description of your assumptions and the physical meaning of each term in your expressions.
   b) Briefly describe (qualitatively) the changes in upwelling and downwelling radiances on the following conditions: i) cloudy day, ii) over western Pacific Ocean versus Kansas, iii) over Sahara versus Amazon.

18) For more than 4 decades, the climate sensitivity parameter (λ_{CS}) is today still the most widely used metric to characterize the magnitude of the Earth's temperature response ΔT_o to changes in radiative forcing ΔF. Simulations using climate models indicate values of λ_{CS} in the range of 0.3-1.4 Km^{2}W^{-1} depending on the model.
   a) Derive λ_{CS} using our simple one-layer model for the atmosphere as a function of f (absorption efficiency), T_o (Earth's mean surface temperature) and σ (Stefan-Boltzman constant). Assume $\lambda_{CS}\,\Delta F = \Delta T_o$ and that increases in greenhouse gases correspond to increases in absorption efficiency $(f + \Delta f)$ leading to changes in radiative forcing ΔF and a new radiative equlibrium with surface temperature $(T_o + \Delta T_o)$. HINT: Find an expression of ΔF as a function of f, $f + \Delta f$, and T_o. Then, find an expression of ΔT_o as a function of F_s, A, $f + \Delta f$, and $T_o + \Delta T_o$.
   b) Calculate λ_{CS} using $f = 0.77$ $(f \gg \Delta f)$ and $T_o = 288$ K. Compare with the range derived from climate models. Briefly explain why your value is different from this range.

19) Discuss how the stratospheric O_3 layer is formed via the Chapman mechanism. While this mechanism can reproduce the observed vertical shape of the O_3 layer, why is it overestimating the absolute magnitude of O_3 concentration by a factor of 2-3?

20) Consider a 60 W incandescent light bulb with a filament having diameter of 0.2 mm and length of 6 cm.
   a) Estimate the temperature of the filament assuming emissivity $\varepsilon = 0.5$.
   b) Find the peak wavelength emitted by this bulb. Is this wavelength with the visible, infrared, or ultraviolet band?
   c) Sketch the radiance B_λ as a function of wavelength for this temperature and roughly estimate the fraction of the total emission of this bulb that falls within the visible portion of the spectrum.

Note: The Planck's function as expressed in terms of frequency ν is defined as:

$$B_\nu(T) = \frac{2h\nu^3}{c^2}\left(\frac{1}{exp^{\left(h\nu/_{k_B T}\right)} - 1}\right)$$

where $h = 6.626e^{-34}$J s, $k_B = 1.381e^{-23}$ J/K, and $c = 2.998e^8$ m/s

ATMO541A: Dynamic I. 20 questions for Ph.D qualify exam (provided by Dr. Xubin Zeng)

Some of the following equations may be useful:

State equation: p = ρRT

Hydrostatic equation: dp/dz = -ρg

geopotential φ: dφ = g dz

vertical derivative is: $\frac{\partial f}{\partial z} = \frac{\partial f}{\partial s}\frac{\partial s}{\partial z}$

horizontal derivatives: $(\frac{\partial f}{\partial x})_s = (\frac{\partial f}{\partial z})_x (\frac{\partial z}{\partial x})_s + (\frac{\partial f}{\partial x})_z$

geostrophic wind $\boldsymbol{V}_g = \boldsymbol{i}u_g + \boldsymbol{j}v_g$ as: $\boldsymbol{V}_g = \boldsymbol{k} \times \frac{1}{\rho f}\nabla p = \boldsymbol{k} \times \frac{1}{f}\nabla_p \phi$

Taylor expansion (with a small Δx): p(x0 + Δx) = p(x0) + $(\frac{dp}{dx})_{x0}$ Δx + ...

Coriolis parameter: f = 2Ω sinφ and 2π/Ω = 1 day

Potential temperature Θ is: $\Theta = T\,(\frac{p_s}{p})^{\frac{R}{c_p}}$

For saturated air: $\theta_e = \theta \exp\left(\frac{L_c q_s}{c_p T}\right)$

For unsaturated air: $\theta_e = \theta \exp\left(\frac{L_c q}{c_p T_{LCL}}\right)$

$\theta_e^* = \theta_e\,(q_s(T), T) = \theta \exp\left(\frac{L_c q_s(T)}{c_p T}\right)$

gradient wind relation: $\frac{V^2}{R} + fV = -\frac{\partial \phi}{\partial n}$ and its solution: $V = -\frac{fR}{2} \mp (\frac{f^2R^2}{4} - R\frac{\partial \phi}{\partial n})^{\frac{1}{2}}$

For a circular pattern of streamlines moving at a constant speed of C, the relationship between the radii of streamlines and trajectories is: $R_s = R_t\,(1 - \frac{C\cos\gamma}{V})$

Circulation $C \equiv \oint \boldsymbol{U} \cdot d\boldsymbol{l} = \oint U\cos\alpha\, dl$

Circulation theorem: $\frac{DC_a}{Dt} = \frac{D}{Dt}\oint \boldsymbol{U}_a \cdot d\boldsymbol{l} = -\oint \frac{dp}{\rho}$

Conservation of absolute circulation: $C_2 + 2\,\Omega\, A_2 \sin\phi_2 = C_1 + 2\,\Omega\, A_1 \sin\phi_1$

Angular momentum = **R**× $\boldsymbol{U}$

Vorticity $\zeta \equiv \boldsymbol{k} \cdot (\nabla \times \boldsymbol{U}) = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$

Potential vorticity $PV \equiv (\zeta_\theta + f)(-g\frac{\partial \theta}{\partial p})$

Shallow-water potential vorticity = $\frac{\zeta + f}{h}$

Near-surface wind: $\bar{u} = \frac{u_*}{k}\ln\frac{z}{z_0}$ with k = 0.4

Vertical velocity at the top of boundary layer: w(De) = $\frac{\zeta_g}{2\gamma} = \zeta_g \left|\frac{K_m}{2f}\right|^{1/2}$

Earth radius a = 6.4×10^6 (or about 10^7) m

Brunt-Vaisala frequency $N = (\frac{g}{\theta_0}\frac{d\theta_0}{dz})^{1/2}$

g = 9.8

c_p = 1004

R = 287

Static stability criteria using Γ or using θ_e^* and θ:

absolutely stable:	$\Gamma < \Gamma_s$;	$\frac{\partial \theta_e^*}{\partial z} > 0$;	$\frac{\partial \theta}{\partial z} > 0$
conditionally unstable:	$\Gamma_s < \Gamma < \Gamma_d$;	$\frac{\partial \theta_e^*}{\partial z} < 0$;	$\frac{\partial \theta}{\partial z} > 0$
absolutely unstable:	$\Gamma > \Gamma_d$;	$\frac{\partial \theta_e^*}{\partial z} < 0$;	$\frac{\partial \theta}{\partial z} < 0$

1). Choose ONE right answer for each question:

- 1a. If temperature is changed by 1 K, it would change by [(a) 0.56ºF, (b) 1ºF, (c) 1.8ºF, (d) 2ºF].

- 1b. Pressure gradient force is a [(a) body force, (b) surface force, (c) both].

- 1c. For a geocentric reference frame; i.e., a frame fixed with respect to the rotating earth, it is [(a) an inertial reference frame, (b) a noninertial reference frame, (c) undecided].

- 1d. [(a) Gravity force, (b) Gravitational force, (c) both gravity force and gravitational force] is perpendicular to the surface of the earth.

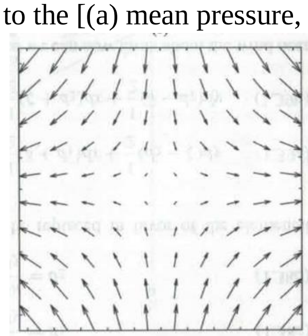
2). Choose ONE right answer for each question:

- 2a. The larger the Rossby number, [(a) the less accurate, (b) the more accurate, (c) with the same accuracy] the geostrophic approximation.

- 2b. Assuming the pressure fluctuation is 10 mb over a horizontal distance L = 1000 km, the geostrophic wind ($\frac{1}{f\rho}\frac{\delta p}{L}$) over midlatitudes can be estimated as [(a) 1 m/s, (b) 10 m/s, (c) 100 m/s, (d) 1000 m/s].

- 2c: The layer thickness between two pressure levels is proportional to the [(a) mean pressure, (b) mean temperature, (c) mean density] of this layer.

- 2d. The flow pattern shown on the right is [(a) pure deformation, (b) pure divergence, (c) pure vorticity].



3). Choose ONE right answer for each question:

- 3a. Boussinesq approximation means [(a) constant temperature except in the buoyancy term, (b) constant density except in the buoyancy term, (c) constant density, (d) constant temperature].

- 3b. The energy conservation equation is: $c_v\frac{DT}{Dt} + p\frac{D\alpha}{Dt} = J$. [(a) $c_v\frac{DT}{Dt}$, (b) $p\frac{D\alpha}{Dt}$, (c) J] term represents the conversion between thermal and mechanical energy.

- 3c. If Γ_d = 10 K/km and Γ = 12 K/km, the atmosphere is [(a) absolutely stable, (b) conditionally unstable, (c) absolutely unstable].

- 3d. The equations [$fV_g = -\frac{\partial\Phi}{\partial n}$, $\frac{V^2}{R} + fV = 0$, $\frac{V^2}{R} = -\frac{\partial\Phi}{\partial n}$] are [(a) geostrophic flow, cyclostrophic flow, inertial flow, respectively; (b) geostrophic flow, inertial flow, cyclostrophic flow, respectively; (c) inertial flow, geostrophic flow, cyclostrophic flow, respectively; (d) cyclostrophic flow, inertial flow, geostrophic flow, respectively].

4). Choose ONE right answer for each question:

- 4a. The gradient wind relation is valid for [(a) streamlines, (b) trajectories, (c) both streamlines and trajectories].

- 4b. The thermal wind is zero for [(a) baroclinic flow, (b) barotropic flow, (c) both baroclinic and barotropic flow].

- 4c. For barotropic fluid, if a closed chain of fluid particles (initially motionless with respect to the earth) is advected across the equator from the Northern Hemisphere to the Southern Hemisphere, [(a) cyclonic circulation, (b) anticyclonic circulation, (c) no circulation] would result.

- 4d. [(a) Vorticity, (b) Circulation, (c) Angular momentum] gives a **macroscopic** measure of the rotation without reference to an axis.

5). Choose ONE right answer for each question:

- 5a. For a circular ring of radius R with constant angular velocity Ω, the circulation is [(a) Ω, (b) 2Ω, (c) ΩR^2, (d) $2\pi\Omega R^2$].

- 5b. The critical flux Richardson number separating unstable and stable turbulence is [(a) -0.25, (b) 0.0, (c) 0.25, (d) 1.0].

- 5c. The TKE equation is: $\frac{\bar{D}(TKE)}{Dt} = MP + BPL + TR - \varepsilon$. For the lower part of atmospheric boundary layer at 11am local time in summer in Tucson, the sign of TR is [(a) positive, (b) negative, (c) zero].

- 5d. Based on the Ekman spiral solution in the atmospheric boundary layer: $u=u_g\,[1 - \exp(-\gamma z)\cos(\gamma z)]$, $v=u_g \exp(-\gamma z)\sin(\gamma z)$, the boundary layer height is defined as the lowest height above surface [(a) at which $u=u_g$ and $v = 0$, (b) at which $u=u_g$, (c) at which $v = 0$].

6) For the homogeneous atmosphere (i.e., constant density with height) with surface temperature T_0 and surface pressure p_0, **(a)** derive the height of the atmosphere, **(b)** compute the height for $T_0 = 0^0$C and p_0 = 1000 mb.

7). At latitude ϕ = 30°N, what are the three components of the earth's rotation vector $\boldsymbol{\Omega}$ in the geocentric coordinate (x axis: eastward, y axis: northward, and z axis: upward)? you need to draw a figure to show the decomposition.

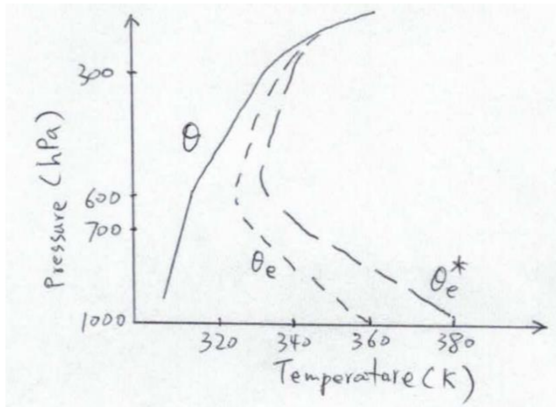
8). Derive (rather than just write down) the adiabatic lapse rate (i.e., the rate of *decrease* of temperature with respect to height under adiabatic condition).

9) For geocentric coordinate with the unit vectors **i**, **j**, and **k** taken to be directed eastward, northward, and upward, respectively, and with the Earth's radius R and at latitude φ, derive $\frac{\partial \mathbf{j}}{\partial y}$ *and* $\frac{\partial \mathbf{k}}{\partial y}$. Note that you need to draw two figures to illustrate your derivations.

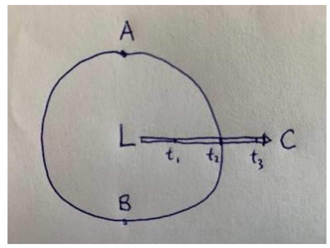
10). Assuming both the atmosphere (P and ρ) and its reference state (p_o and ρ_o) are in hydrostatic balance [i.e., $\frac{1}{\rho}\frac{\partial p}{\partial z} + g = 0$; $\frac{1}{\rho_0}\frac{\partial p_0}{\partial z} + g = 0$], derive the hydrostatic equation for the perturbations of p and ρ (p' and ρ') (e.g., $p = p_o + p'$). Hint: use the Taylor expansion.

11). Derive the approximate relation between dh and $d(\ln\theta_e)$ for saturated parcel with moist static energy $h = c_pT + gz + L_cq_s$

12). For the schematic sounding in the figure,
(a) what is the stability of the atmosphere (absolutely stable, conditionally unstable, or absolutely unstable) beween surface and 700 mb, and what is the criterion you used (make sure you provide the complete criterion)?
(b) what is the stability (absolutely stable, conditionally unstable, or absolutely unstable) of the atmosphere between 600 mb and 300 mb, and what is the criterion you used?
(c) Draw the trajectory of a parcel near surface (moving upward) in the figure, and indicate the location (height) when the parcel becomes absolutely unstable, and what is the name of that height?
(d) Draw the trajectory of a parcel at 700 mb (moving upward) in the figure, and indicate the location (height) when the parcel becomes absolutely unstable.



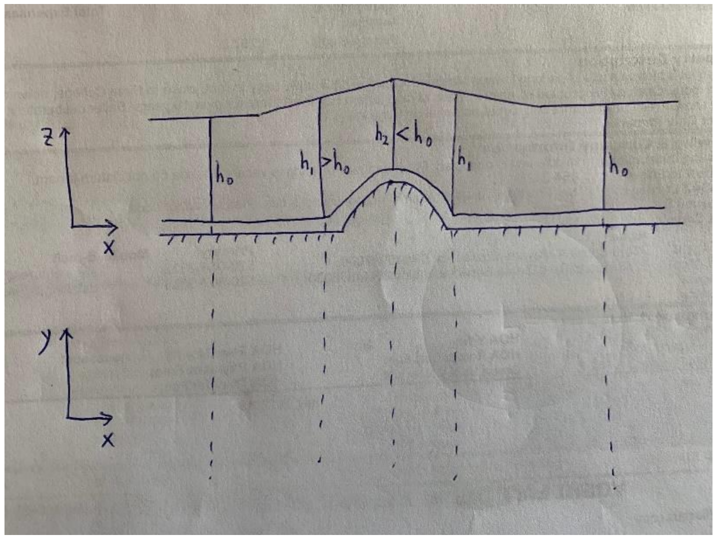
13). In the figure, **(a)** plot the trajectories of two particles starting from points A and B for circular **cyclonic** pattern of streamlines (moving at a constant velocity C) in the **Northern** Hemisphere with the velocity along the streamline being V = 2C; and **(b)** write down the equation and the range of parameter values to justify your drawn trajectories in **(a)**. Numbers indicate positions at successive times. The L designates a low pressure center.



14). For R < 0 and $\frac{\partial \Phi}{\partial n} > 0$ in the gradient wind relation over **Northern** Hemisphere, **(a)** discuss the (physical or un-physical) nature of the positive and negative roots; **(b)** for the physical solution, draw the figure of the balance among three forces; and **(c)** what is the name of the weather system for the physical solution (regular low, anomalous low, regular high, or anomalous high)?

15). A cylindrical column of air at 30°N (**Note** this is for Northern Hemisphere) with radius 50 km expands to twice its original radius. If the air is initially at rest, **(a)** what is the mean tangential velocity at the perimeter after expansion? and **(b)** Is this cyclonic or anticyclonic?

16). For the westerly flow (with initial zero relative vorticity) over a topographic barrier with the depth of a fluid column as a function of x (provided), based on the conservation of shallow-water potential vorticity, **(a)** provide the sign of ζ at each location (h_0, h_1, h_2) in the (x,z) plane; and **(b)** plot the trajectory of a parcel in the (x,y) plane. Note that you need to write down the relevant equation.



17). Based on the definition of θ, derive the hydrostatic equation $\frac{\partial(c_p T + \Phi)}{\partial \theta} = \frac{c_p T}{\theta}$.

18). If the wind at 700 hPa ($\mathbf{U_g}$) is northwesterly in Tucson, AZ, graphically show **(a)** the direction and magnitude (relative to that of $\mathbf{U_g}$) of near-surface wind ($\mathbf{U}$), and **(b)** the directions of three relevant forces that are in balance.

19). **(a)** What do we mean by "secondary circulation" related to atmospheric boundary layer? **(b)** what variables or parameters does it depend upon (**hint**: you could use the expression of the vertical velocity at the top of boundary layer)? **(c)** Describe the main mechanisms that slow down a stirred cup of tea?

20) The mean temperature in the layer between 750 and 500 hPa decreases eastward by 3K per 100 km. If the 750 hPa geostrophic wind is from the southeast at 20 m s^{-1}, **(a)** what is the thermal wind between 750 and 500 hPa (x/y components)? **(b)** what is the geostrophic wind (x/y components) at 500 hPa? and **(c)** show these three winds (wind at 750 and 500 hPa and thermal wind) and indicate "warm" and "cold" locations in a figure. Let $f = 10^{-4}$ s^{-1}. **Hint**: you need to derive the thermal wind relation as a function of temperature gradient in the isobaric coordinate.

ATMO541B: Dynamics II. 20 questions for Ph.D qualify exam (provided by Dr. Atallah, Eyad)

Some useful equations

$$\frac{d\vec{v}}{dt} = -f\hat{k}\ x\ \vec{v} - \nabla\Phi + \vec{F} \qquad \vec{v_g} = \frac{1}{f}\hat{k}\ x\ \nabla_p\Phi \qquad f = 2\Omega sin\phi$$

$$\frac{\partial p}{\partial z} = -\rho g$$

$$(z_2 - z_1) = \frac{R_d\bar{T}}{g} ln\left(\frac{P_1}{P_2}\right)$$

$$\overrightarrow{v_T} = \overrightarrow{v_{g2}} - \overrightarrow{v_{g1}} = \frac{g}{f}\hat{k}\ x\ \nabla_p(z_2 - z_1) = \frac{R_d}{f}\ln\left(\frac{p_1}{p_2}\right)\hat{k}\ x\ \nabla_p T$$

$$\overrightarrow{v_a} = \frac{1}{f}\hat{k}\ x\ \frac{d\vec{v}}{dt} \qquad \overrightarrow{v_{isal}} = -\frac{1}{f^2}\nabla_p\frac{\partial\Phi}{\partial t}$$

$$\nabla_p \cdot \vec{v} = \frac{-\partial\omega}{\partial p} \qquad \nabla_p \cdot \vec{v} = \frac{-\partial\omega}{\partial p} \qquad \zeta_g = \frac{g}{f_o}\nabla_p^2 z \qquad \frac{\partial p}{\partial z} = -\rho g$$

$$\frac{\partial\zeta_g}{\partial t} = -\overrightarrow{v_g}\cdot\nabla_p(\zeta_g + f) - \delta(\zeta_g + f)$$

$$\frac{\partial T}{\partial t} = -\overrightarrow{v_g}\cdot\nabla_p T + \omega\sigma\frac{p}{R}$$

$$X = \frac{\partial\Phi}{\partial T}$$

$$(\nabla^2 + \frac{f_o^2}{\sigma}\frac{\partial^2}{\partial p^2})X = f_o[-\overrightarrow{v_g}\cdot\nabla_p(\zeta_g + f)] - \frac{f_0^2}{\sigma}\frac{\partial}{\partial p}[\frac{R}{p}(-\overrightarrow{v_g}\cdot\nabla_p T)]$$

$$\left(\nabla^2 + \frac{f_o^2}{\sigma}\frac{\partial^2}{\partial p^2}\right)\omega = \frac{-f_o}{\sigma}\frac{\partial}{\partial p}[-\overrightarrow{v_g}\cdot\nabla_p(\zeta_g + f)] - \frac{R}{\sigma p}\nabla_p^2(-\overrightarrow{v_g}\cdot\nabla_p T)$$

$$q = \frac{1}{f_o}\nabla^2\Phi + f + \frac{\partial}{\partial p}(\frac{f_o}{\sigma}\frac{\partial\Phi}{\partial p}) \qquad \frac{Dq}{DT} = 0$$

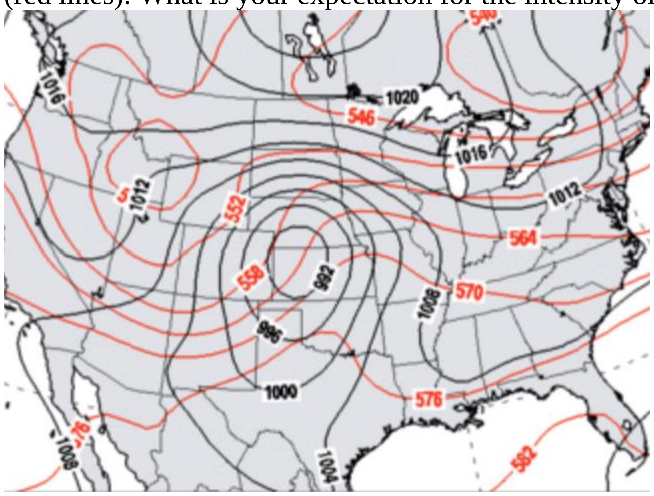
$$\vec{Q} = \frac{-R}{P}\left|\frac{\partial T}{\partial y'}\right|\hat{k}\times\frac{\partial\overrightarrow{v_g}}{\partial x'} \qquad (\sigma\nabla^2 + f_0^2\frac{\partial^2}{\partial p^2})\omega = -2\nabla_p\cdot\vec{Q}$$

$$PV = -g(\zeta_\theta + f)\frac{\partial\theta}{\partial p}$$

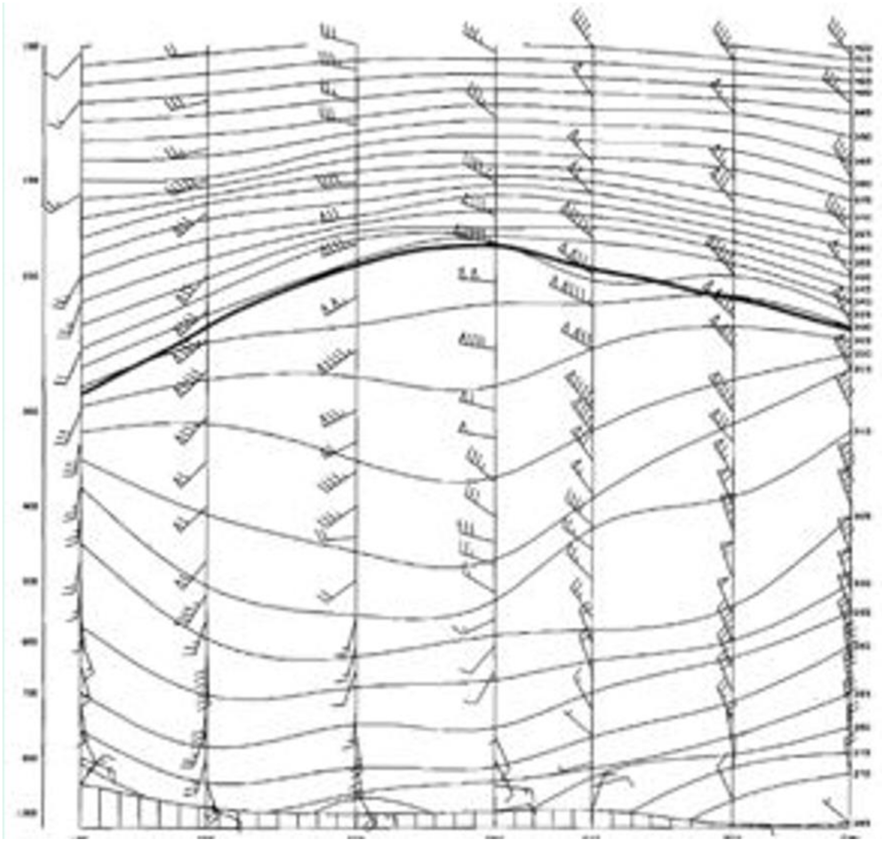
1) Discuss why the Jet Stream can roughly be used as a proxy for the tropospheric temperature distribution.
2) What is the expected pattern of ageostrophic divergence around a relatively straight jet streak.
3) Discuss the relationship between horizontal temperature advections and vertical motions. Be sure to include in your discussion concepts such as the isallobaric wind and mass continuity.
4) Explain the observation that horizontal warm-air advection in the presence of a stable static stability can result in a local decrease in temperature.
5) What are the implications of local increases in the geostrophic relative vorticity on the geopotential or pressure field? Include in your answer a discussion of the implication of the Laplacian operator.
6) Use the simplified geostrophic vorticity equation $\frac{\partial\zeta_g}{\partial t} = -\overrightarrow{v_g}\cdot\nabla_p(\zeta_g + f) - \delta(\zeta_g + f)$

to show that, following the flow, $\eta_f = \eta_i e^{-\delta t}$ where $\eta = (\zeta_g + f)$ and the subscripts I and f refer to initial and final values respectively.

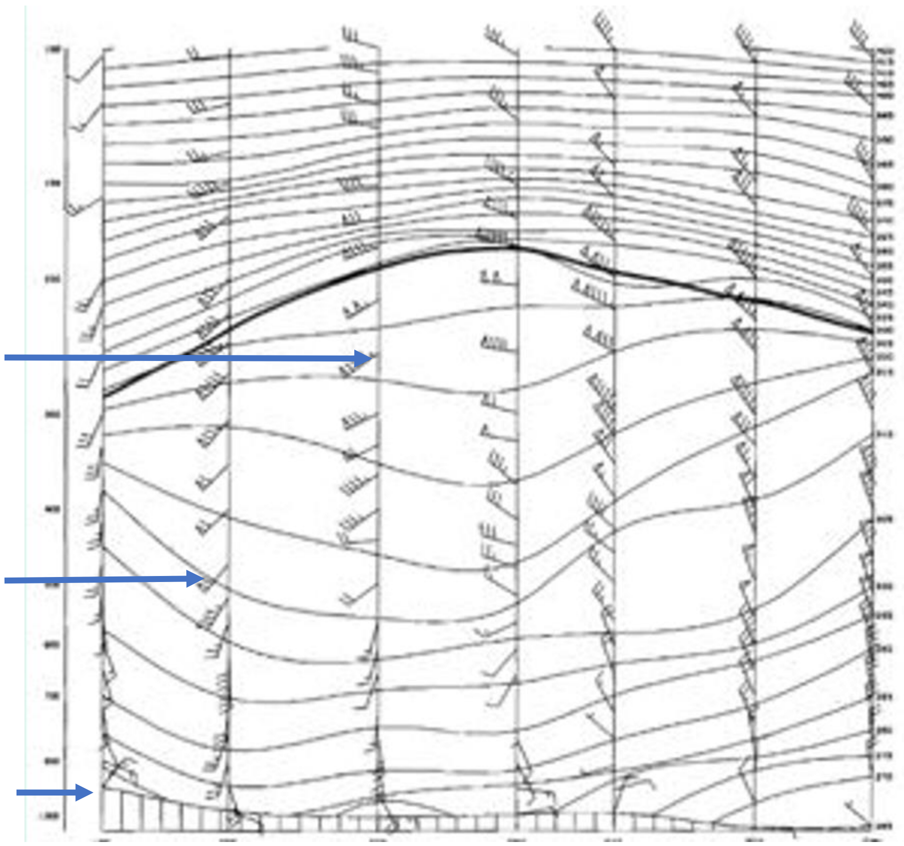
7)Explain the propensity for cyclogenesis to occur on the lee side of mountain ranges.
8)Use Quasigeostrophic Theory to discuss the implications of wavelength and amplitude on upper-tropospheric wave propagation.
9)Why is baroclinic development characterized by an upshear tilt with respect to the windshear vector?
10)Explain the relationship of the tilt (positive/negative) of the upper-tropospheric wave to the intensity of surface development.
11)Use Quasigeostrophic Theory to explain why surface cyclones generally propagate towards the northeast in the Northern Hemisphere.
12) Discuss why cyclogenesis tends to be most intense in the cool season along the eastern coasts of most continents.
13)What are the implications of a Q-vector that points towards warm air?
14)Consider the following image of mean-sea level pressure (black lines) and 1000-500 hPa thickness (red lines). What is your expectation for the intensity of the cyclone situated over western Nebraska?



15)Use Quasigeostrophic Potential Vorticity to assess the expected tendency of relative vorticity for a column of air approaching a mountain barrier.
16)What is an advantage of the Q Vector formulation of the QG omega equation relative to the traditional form of the equation?
17)Discuss the impact of strong condensational heating in the middle troposphere on the vertical distribution of Isentropic Potential Vorticity.
18)For the situation above, where would you expect a negative surface Isentropic Potential Vorticity Anomaly to develop.
19)Consider the following distribution of isentropes in a cross-section. Does this schematic best represent a positive or negative upper-level Isentropic Potential Vorticity anomaly?



20)Consider the same isentropic cross section above. Assuming that the mean wind is westerly and increasing with altitude (blue arrows), diagnose and area of descent.



General Section in Remote sensing and climate change: 20 questions for Ph.D qualify exam (Provided by Dr. Ali Behrangi)

a) Remote sensing

1- How do you define “remote sensing “ ?
2- Can satellites help study hydrology and atmospheric science? How? Explain
3- Which components of the water cycle are observable by satellites? Give examples.
4- Why do you think remote sensing is important for studying the Earth?
5- Have you heard about the Global Precipitation Measurement (GPM) mission? What is it?
6- What does make Active sensor sdifferent from Passive sensors in remote sensing?
7- How is electromagnetic radiation related to remote sensing?
8- Does sun radiate? How about the Earth? What makes them different? discuss
9- Why Sky is blue? Do you think moon’s sky is also blue?
10- Assume you want to design a sensor to measure surface soil moisture from space. What important factors should be considered to design a successful sensor that can provide useful information at all times?
11- Have you heard about “Geostationary satellites”? Do you know what makes them different from other types of satellites?

b) Climate change

12- How do you describe “Global warming”? What is happening and why?
13- Have you heard about greenhouse gases? Can you name few of them? How they are related to the global warming?
14- Why in the global warming context most people talk about CO_2? What makes this gas so important?
15- What do you know about IPCC? Explain
16- Do you have any idea by the end of the century how much increase in mean global temperature is expected?
17- In the warming climate land gets warmer faster or ocean? Why?
18- In the warming climate, do you think there is a latitudinal dependence to the warming? In other words to you think higher latitudes get warmer faster or lower latitudes? Any idea why?
19- Explain what does “mitigation” and “adaptation” mean in the context of climate change
20- Discuss how global warming can impact water resources management and planning.