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EVST201a/G&G 140a

The Atmosphere, Ocean and Environmental Change

Final Exam (2011)

Useful physical and mathematical constants:

$R = 8314\ J/kmole \cdot Kelvin$; $\sigma = 5.735 \times 10^{-8} Wm^{-2}K^{-4}$; $\pi = 3.14159$ $G = 6.674 \times 10^{-11} m^3 kg^{-1} s^{-2}$

Earth parameters:

$R_E = 6371 km$; $a_E = 0.33$; $g = 9.81\ m/s^2$, $\Gamma = -g/c_p = -9.8^oC/km$, $Tilt = 23.5^o$

$H_S = R_a T/g \approx 8.4 km$; $S = 1380\ W/m^2$; $\Omega = 7.27 \times 10^{-5}\ s^{-1}$; $M = 5.974 \times 10^{24} kg$

Properties of air:

$R_{air} = 287 J/kg.C$; sea level $\rho_{air} = 1.2 kg/m^3$; $C_{P_{Air}} = 1004 J/kg^\circ C$

Properties of water:

$\rho_{water} = 1000 kg/m^3$; $\rho_{ice} = 917 kg/m^3$; $\rho_{SEA} = 1025 kg/m^3$

$L_{COND} = 2.5 * 10^6 J/kg$; $L_{FREEZE} = 3.34 \times 10^5 J/kg$

$C_{P_{Water}} = 4218 J/kg^\circ C$

Useful definitions:

$RH = P/P_{sat}$; $ResTime = C/F$; $\delta D = [\left(\frac{D}{H}\right) / \left(\frac{D}{H}\right)_{REF} - 1] \times 1000$

Useful physical laws and balances:

$gM = PA$; $F_G = \frac{GMm}{r^2}$; $p = \rho RT$; $\Delta p = -\rho g \Delta Z$; $Rgas = Runiversal/M$

$V_e = \sqrt{2gR_E}$; $V_m = \sqrt{\frac{3RT}{M}}$; $Q = MC_P\Delta T$; $Q = L\Delta m_v$

$R = \sqrt{K \cdot T}$; $R_{plume} = \sqrt{Kx/U}$;

$CF = 2MU\Omega\sin\phi$; $\tau = 0.003\rho_A U_A^2$; $U_{EKMAN} = \frac{\tau}{2\rho D\Omega sin\phi}$

$F = \sigma T^4$; $\lambda_m T = 2898 \text{microns}\ ^\circ K$

$PET(mm/month) \cong 5 \times T(C)$; $P = P_0 e^{-Z/H}$; $\rho = \rho_0 e^{-Z/H_S}$

$T = \sqrt[4]{\frac{S(1-a)}{4\sigma}}$; $T_{GH} = T/(1-\frac{\varepsilon}{2})^{1/4}$

$A_S = 4\pi R^2$; $V = (4/3)\pi R^3$; $F = Scos(\varphi)$; $\Delta T = \frac{Q/A}{\rho D C_P}$, $\Delta S = S_1(\frac{-d}{D+d})$

$WaterFlux = \rho_W UA$; $SaltFlux = S\rho_W UA$; $HeatFlux = C_P T\rho_W UA$

$(\Delta p / L)\, Vol = \rho \times 2 \times \Omega \times \sin\phi \times U \times Vol$

$PE = Mgz$; $EFF = \Delta T/T$; $Qout = K\sqrt{Zeff}$, $P(t) = P(t=0)\exp(\gamma t)$

$P_{Wind} = (\frac{1}{2})\varepsilon\rho U^3 A$, $P_{Solar} = \varepsilon S\tau_A A\cos(\varphi)$, $P_{HYDRO} = \varepsilon R\rho_W gzA$

Unit Conversions:

$ppmv = \frac{M_{AIR}}{M}\, ppmm$; *1 mb = 100 Pascals;* $0°C = 273.1\ K$; $1SV = 10^6 m^3 s^{-1}$

1 knot = 0.54 m/s; 1 inch = 2.54 cm; $°C = \frac{5}{9}(°F - 32)$ $1\ tonne = 10^3 kg$

T (°C)	P_{sat} (mb)
-10	2.9
0	6.1
10	12.3
20	23.4
30	42.4

Molecular Weights	
H_2	2
N_2	28
O_2	32
CO_2	44
Air	29

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1. [4] A planet in a distant galaxy has a solar constant of 3000W/m2, a radius of 12,000km and an albedo of a=0.6.

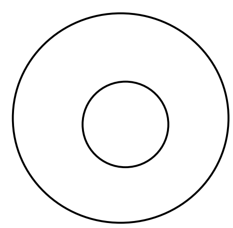
a. Estimate the surface temperature of the planet.

b. List the assumptions you made.

2. [3] Explain qualitatively, using the concept of escape velocity, why earth has an atmosphere dominated by N_2 with little H_2 or He.

3. [4] Consider the circular isobars in a southern hemisphere cyclone shown below.

a. Indicate the high and low pressure regions of the cyclone
b. At one point in the cyclone, sketch and label vectors representing the wind, pressure gradient force and Coriolis force.



4. [4] Air in a large rectangular valley (5km by 20km) is capped by an elevated inversion at z=800m. Into this valley, 100kg of toxic gas is released and distributed. Find the toxic gas concentration. Give units.

5. [3] Explain why clouds form in rising air.

6. [3] Explain why most clouds do not precipitate.

7. [4] A HAWT wind turbine with blade length of 10 meters experiences a steady 10 m/s wind. Assuming that the turbine efficiency is 40%, estimate the total energy generated in 24 hours. Express your answer in both **Joules** and **kWhr**.

8. [4] Consider a reservoir of water with dimensions 5km by 10km with 10 meters of standing water. The water drains from the reservoir into a large pipe (i.e. the penstock) and falls 100 meters into a turbine with efficiency of 30%. Estimate the total electrical energy that can be generated by draining the reservoir.

9. [4] Explain the advantages or disadvantages of electricity generation from natural gas compared to coal in regard to

a. a) local air pollution (e.g. SO_2, NO and HgO)

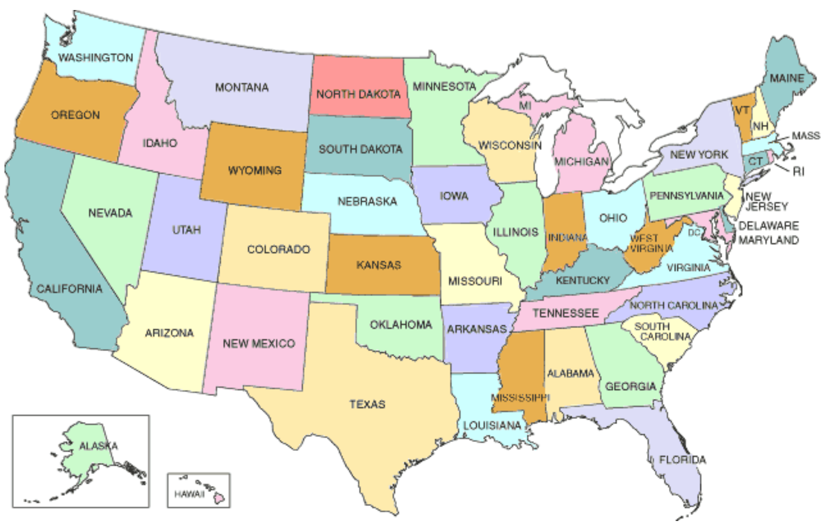
b. b) CO_2 emissions

10. [6] On the USA map provided, circle the areas best suited for three types of renewable energy and explain why below.

a. Wind energy

b. Solar

c. Hydroelectric



11. [3] Where and when does the ozone hole appear? Explain why?

12. [3] During a Pleistocene glacial period the $^{18}O/^{16}O$ ratio in ocean sediments became *greater* or *less* (circle one) than during an interglacial period. Explain why?

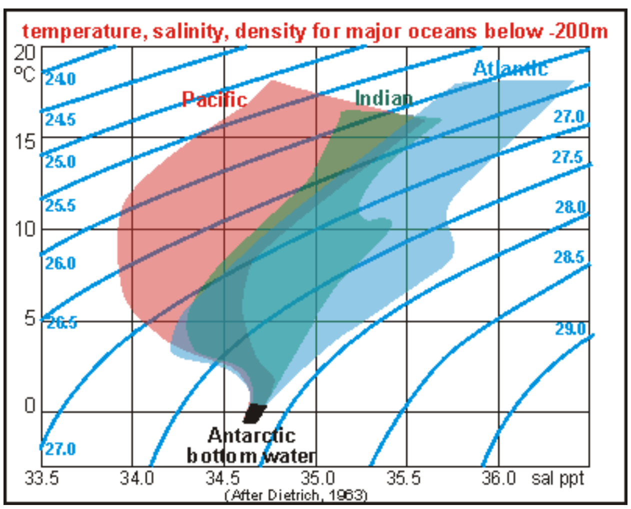
13. [4] The North Atlantic Gyre moves 50SV of water northward with T=20C and an equal amount of water southward with T=10C. Compute the net rate of northward heat transport by these currents.

14. [4] At a point in the South Pacific Ocean at 20S latitude, an easterly wind blows over the ocean with speed 10m/s. Determine the average direction and speed of the Ekman Drift. Assume that the wind stress is felt down to a depth of 50 meters.

15. [4] Consider a location in the ocean where the sea water temperature is 5C and the salinity is 34.5ppt.

a. What is the density of this water?

b. How much does the pressure increase for every ten meters of added depth?



16. [4] If the partial pressure of water vapor is 20mb and the temperature is 20C determine the

a. The water vapor density

b. The relative humidity

17. [4] Consider a day with surface temperature of 10C and a constant tropospheric lapse rate of -6.5C/km. A parcel of air is lifted adiabatically from the surface to z=4km. Determine the temperature of the
   a. lifted parcel
   b. air surrounding the parcel

18. [5] Consider two Sites on earth with clear skies. Site A has a surface temperature of 30C, an albedo of 0.1 and a solar zenith angle of 20 degrees. Site B has a surface temperature of -10C and albedo of 0.6 and a solar zenith angle of 60 degrees.
   a. Compute the absorbed solar radiation per unit area at each site.
   b. Compute the emitted long wave radiation per unit area at each site.
   c. Is either Site in a state of near radiative balance?

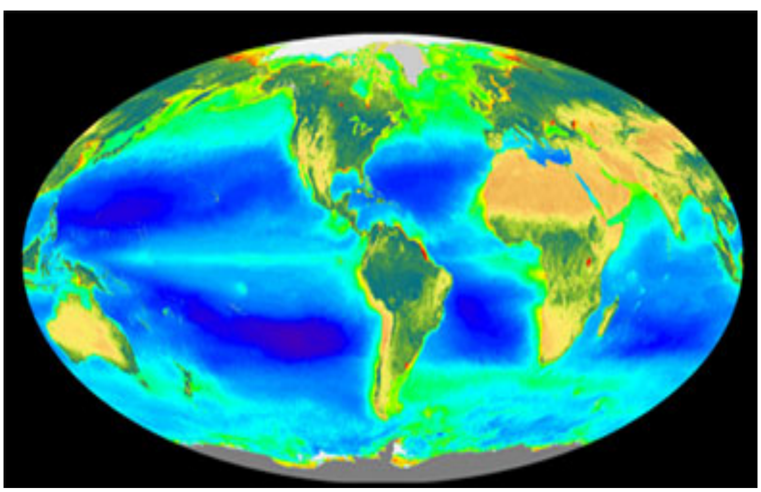
19. [3] Explain why the sky appears blue but a cloud appears white.

20. [3] Consider a human population of 6 billion in the year 2000. Estimate the population in the year 2100 assuming that the population growth rate is 0.005 /yr.

21. [4] Consider, due to increased greenhouse gases, that the downward longwave radiation at the earth's surface increases by 3W/m2. If this is the only change in the ocean heat budget, how much will the ocean warm in one year? Assume that only the top 100 meters of the ocean is affected.

22. [3] In an early winter storm in the mountains of New England, the mountain tops received snow and the valley bottoms had freezing rain. Explain how this might happen, using appropriate sketches of the temperature profile and mountain height.

23. [3] Referring to the ocean chlorophyll distribution shown below, describe briefly the general physical and biological processes that cause the ocean productivity to vary spatially.



24. [6] **Explain** the reason for the rainy season at each location below. **Estimate** the net water added to the soil (i.e. P-E) in the wettest month.

    a. **Valparaiso, Chile** (Lat =33S, Long = 72W) The wettest month is June (P = 5.9 inches; temperature of T = 56F). The driest month is February (P=0; T=66F).

    b. **Mexico City, Mexico** (Lat=19N, Long=100W) The wettest month is August (P=4.6 inches, T=62F). The driest month is January (P=0.2 inches, T=54F)

25. [8] Define the following terms

a. El Nino

b. Stratosphere

c. NADW

d. Cirrus

e. Esker

f. Cold front

g. Little Ice Age

h. Pancake Ice