8.51 1. a) Planetary albedo $= \dfrac{8+17+6}{100}$

$= 0.31$

b) Surface albedo $= \dfrac{6}{52} = 0.12$

$[100 - 8 - 17 - 19 - 4 = 52]$

SEE FOLLOWING PAGE

c) Surface radiative temperature.

Outgoing longwave

$$Q_e = 1.15 \times 342 \ \mathrm{W\,m^{-2}}$$

$$= 393 \ \mathrm{W\,m^{-2}}$$

$$= \sigma T^4$$

$$\therefore T = \left[\frac{393}{5.78 \times 10^{-8}}\right]^{\frac{1}{4}} \quad \frac{\mathrm{W\,m^{-2}}}{\mathrm{W\,m^{-2}\,K^{-4}}}$$

$$= 287.2 \ \mathrm{K}$$

$$= 14\ ^\circ\mathrm{C}$$

d) Latent heat flux

$$Q_e = 0.24 \times 342 \ \mathrm{W\,m^{-2}}$$

$$= 82.1 \ \mathrm{W\,m^{-2}}$$

This represents evaporation, and on a planet average basis $E = P$.

$\therefore$ Take latent heat of vaporization, as

$$\lambda_v = 2.5 \ \mathrm{MJ/kg}$$

$$\therefore P = E = \frac{82.1}{2.5 \times 10^6} \quad \frac{\mathrm{J\,s^{-1}\,m^{-2}}}{\mathrm{J\,kg^{-1}}}$$

$$= 32.8 \times 10^{-6} \ \mathrm{kg\,s^{-1}\,m^{-2}}$$

$\times 3600 \times 24 \times 365.25$

$$\Rightarrow 1036 \ \mathrm{kg\,m^{-2}\,yr^{-1}}$$

9.02 $\Rightarrow$ 1036 mm yr^{-1}

Utah State University
Department of Civil and Environmental Engineering
CEE 6400 Physical Hydrology

Midterm exam. Date: 10/19/2009
D.G. Tarboton Time: 75 min
60 Points

Open Book. Answer all questions. Please answer on separate sheets of paper. You may refer to the textbook, notes, solutions to homeworks and any other written or printed reference material that you have brought with you.
Calculator use. You may use a programmable calculator or equivalent calculating device (e.g. calculator functionality on a phone). You should limit the use of the calculating device to the performance of calculations. You may use programs that you have written to evaluate quantities commonly used in this class (e.g. saturation vapor pressure). You may not use your calculating device to retrieve stored reference material in any form. You may not send messages or access the internet or communicate in any way with anyone other than the instructor or moderator regarding solutions to these questions.

1. Consider the earth's radiation balance as depicted in the figure below

100 − 8 − 17
− 19 − 4
= 52

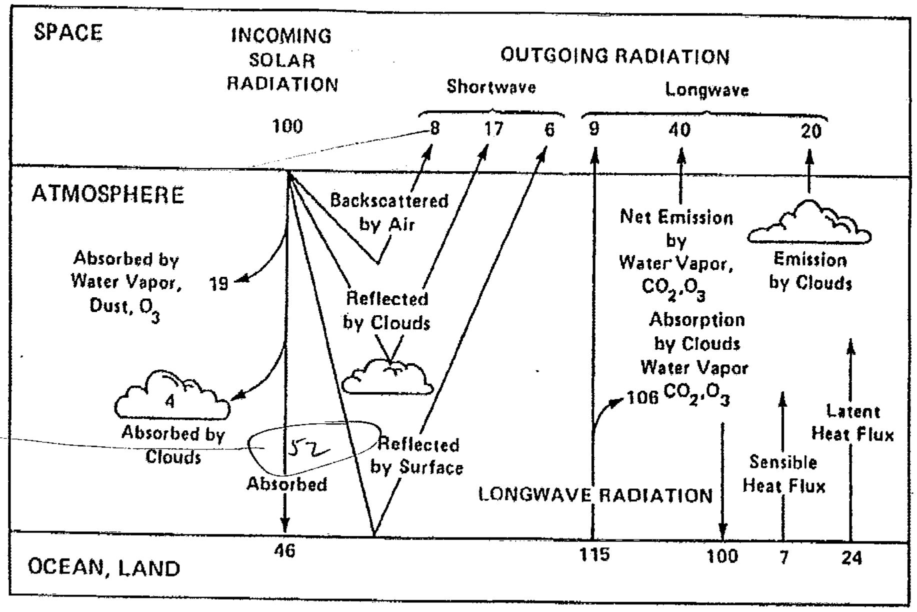


FIG. 6. Schematic representation of the atmospheric heat balance. The units are percent of incoming solar radiation. The solar fluxes shown on the left-hand side, and the longwave (thermal IR) fluxes are on the right-hand side (from MacCracken and Luther 1985).

In this figure 100 units of incoming solar radiation may be equated with the planetary average solar radiation forcing of 342 W/m^2.

Estimate based on values from this figure

a) The planetary albedo [5]
b) The surface albedo [5]
c) The surface radiative temperature (a planetary average) [5]
d) The planet average precipitation [5]

[20 points]

8.25

2. a) Water Balance is

$E = P - Q$

Express Q on a per unit area basis

Region A

Gain Flow = Gauge 2 − Gauge 3 − Gauge 4

$= 6.4 - 2.4 - 2.3$

$= 1.7 \ m^3/s$

$\div \left(62 \ km^2 \times 10^6 \ m^2 \ km^{-1}\right)$

$\times \ 3600 \times 24 \times 365.25 \ s \ yr^{-1}$

$\Rightarrow \frac{1.7}{62 \times 10^6} \times 3600 \times 24 \times 365.25$

$= 0.865 \ m = 865 \ mm$

$\therefore E = P - Q = 1400 - 865 = \underline{535 \ mm}$

$RR = Q/P = 865/1400 = \underline{0.62}$

B. $Q = \frac{2.3}{75 \times 10^6} \times 3600 \times 24 \times 365.25$

$= 0.968 \ m = 968 \ mm$

$\therefore E = 1600 - 968 = \underline{632 \ mm}$ $\quad Q/P = \underline{0.61}$

C $Q = \frac{7.7 - 6.4}{50 \times 10^6} \times 3600 \times 24 \times 365.25$

$= 0.820 \ m = 820 \ mm$

$\therefore E = 1300 - 820 = \underline{480 \ mm}$ $\quad Q/P = \underline{0.63}$

D. $Q = \frac{2.4}{58 \times 10^6} \times 3600 \times 24 \times 365.25$

$= 1.306 \ m = 1306 \ mm$

8.36 $\therefore E = 1900 - 1306 = \underline{594 \ mm}$ $\quad Q/P = \underline{0.69}$

b) Changes in watershed A will only affect flow of gages 1 and 2, as gages 3 and 4 are upstream.

Generally runoff increases from urban areas due to increases in pervious areas and reduction in ET. However, increased garden water use can increase ET (and reduce Q) if the source is precipitation water. Here an increase in Q seems more likely since the question does not say anything about water from P being used in the urban area for lawn watering, or systems to facilitate this.

- Extreme case - NO ET from area converted to urban => 20 % reduction in ET.

=> ET goes to 428 mm averaged over the whole watershed (ET is still 535 mm in unchanged areas).

∴ $Q = 1400 - 428 = 972$ mm

Converting to m^3/s

$$Q = \frac{0.972 \times 62 \times 10^6}{3600 \times 24 \times 365.25} = 1.91 \ m^3/s$$

This suggests a $0.21 \ m^3/s$ increase of gages 1 and 2

This is the upper bound. All P goes to Q.

Lower bound — less likely, urban irrigation replaces all P for 20 % of area.

∴ No runoff from this area

∴ Q reduced by 20% ie $0.2 \times 1.7 = 0.34 \ m^3/s$

8-51 ∴ Max increase $0.21 \ m^3/s$, Max reduction $0.34 \ m^3/s$ of gages 1 and 2

3\. a) On the Pseudo adiabatic diagram at 1300 m and 6°C, I read saturation mixing ratio (Point A)

$= 7 \ g/kg = 0.007$.

[Using

$$e_s = 6.108 \exp\left(\frac{17.27 \times 6}{237.3+6}\right)$$

$$= 9.351 \ hPa$$

at $P = 860$ hPa (from diagram for 1300 m)

$$q_s = \frac{0.622 \ e}{P} = \frac{0.622 \times 9.351}{860}$$

$$= 0.0068$$]

Since RH = 80%

$$q = 0.8 \times 0.0068 = 0.0054$$

b) Point B on diagram 1700 m

or 400 m above the lake.

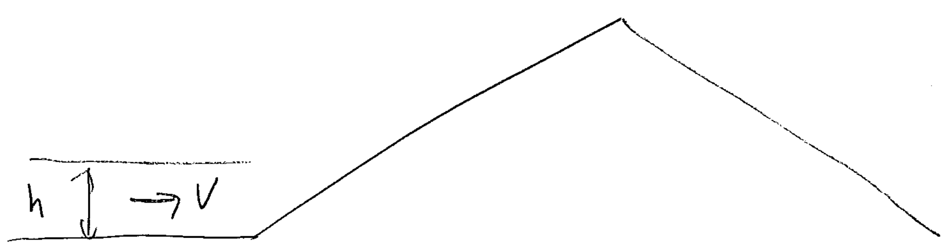
c) Snow / freezing level 2100 m

Point C on diagram

d) Point D on diagram 0.0038

e) $\therefore \frac{0.0054 - 0.0038}{0.0054} = 0.296$ Fraction of moisture that condenses.

f)



f) Density of incoming air

$$\rho_a = \frac{p}{RT} = \frac{860 \times 10^2}{287 \times (273+6)} \quad \frac{N\,m^{-2}}{J\,kg^{-1}\,K^{-1}\,K}$$

$$= 1.074 \quad kg\,m^{-3}$$

$$\therefore \rho_v = 0.0054 \times 1.074 = 5.8 \times 10^{-3} \quad kg\,m^{-3}$$

∴ water vapour across interface

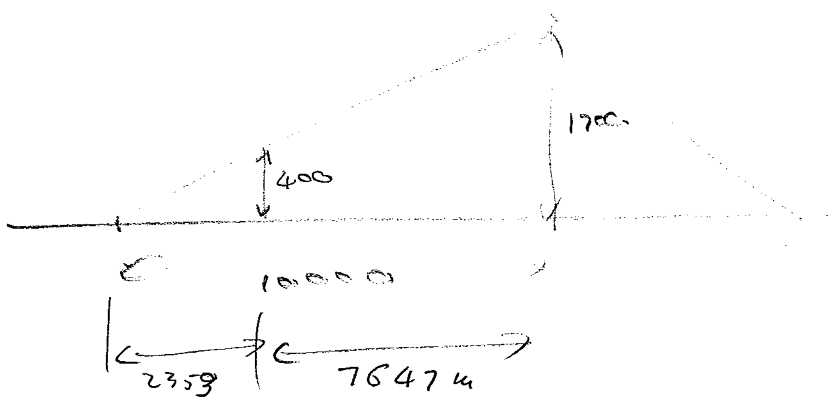
$$\Rightarrow \rho_v V h = 5.8 \times 10^{-3} \times 4 \times 300 \quad kg\,m^{-3}\,m\,s^{-1}\,m$$

$$= \underline{6.96 \quad kg\,m^{-1}\,s^{-1}}$$

This is per m width of the flow.

Of this 0.296 falls as precip,

and it is spread from condensation level to the top of the mountain



$$\therefore \text{Precip rate} = \frac{6.96 \times 0.296}{7647} \quad \frac{kg\,m^{-1}\,s^{-1}}{m}$$

$$= 0.269 \times 10^{-3} \quad kg\,m^{-2}\,s^{-1}$$

$\times 3600 \Rightarrow 0.97 \quad kg\,m^{-2}\,hr^{-1}$

$= \underline{0.97 \quad mm\,hr^{-1}}$

9.28

9.31 J) Returning from 3000 m down dry adiabat to 1300 m, point B.

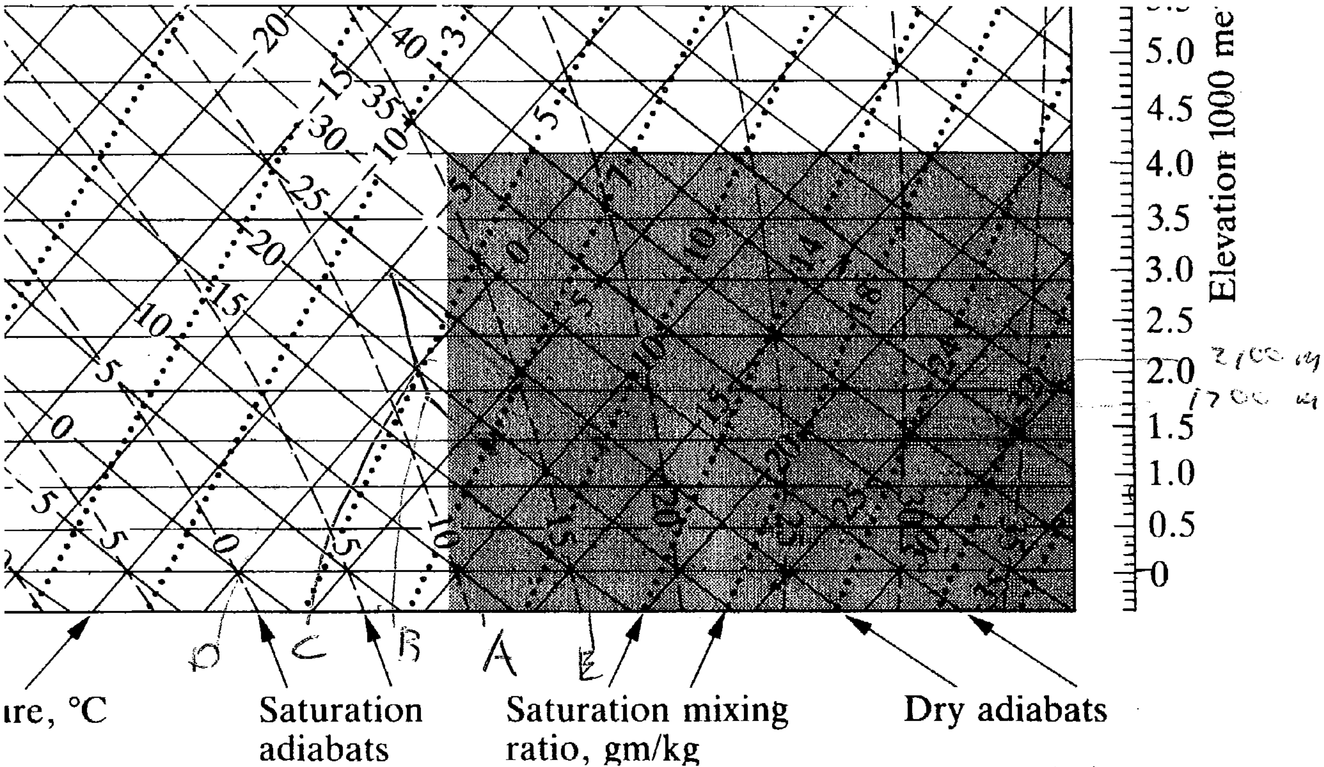
$T = 12^{\circ}C$

Saturation specific humidity = 0.01

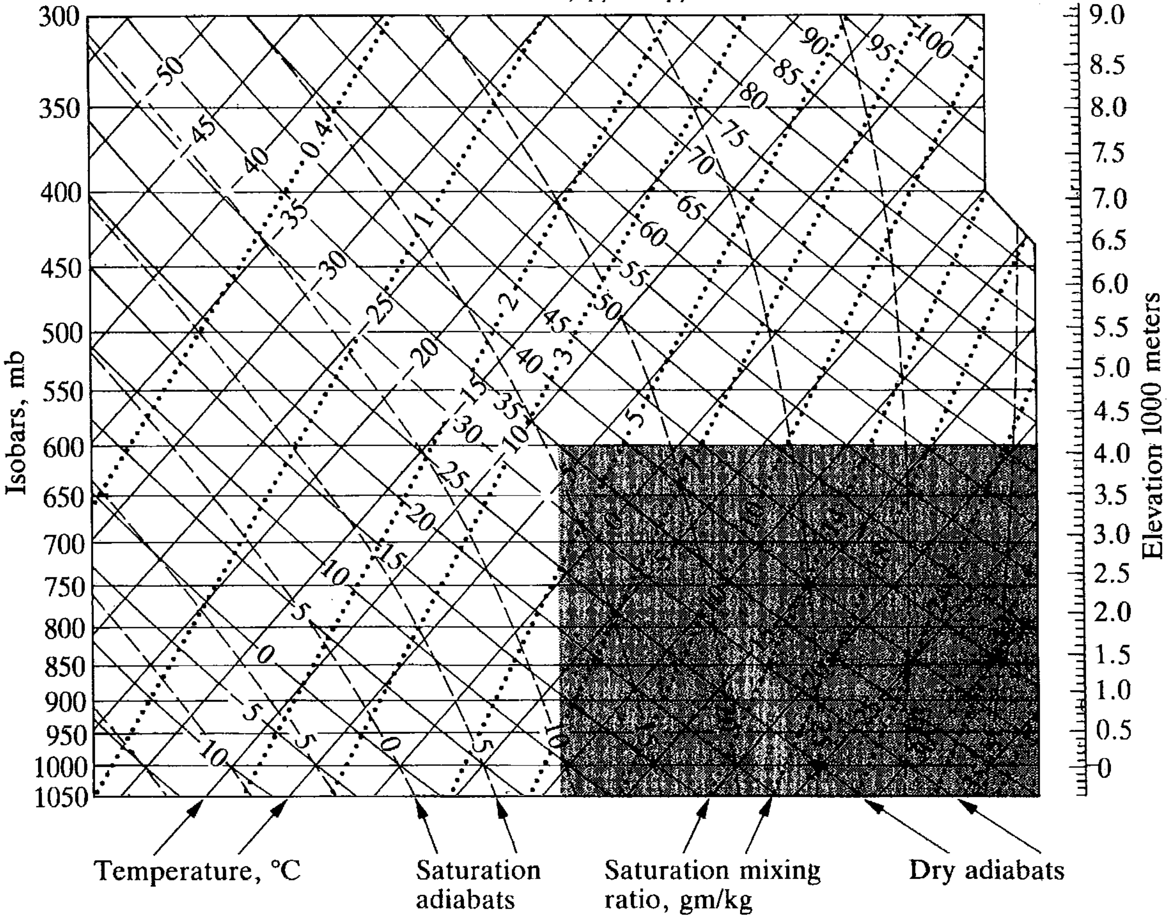
Specific humidity from 3000 m = 0.0038

∴ Relative humidity = 0.38 = 38%

Name: ________________________________



ıre, °C
Saturation adiabats
Saturation mixing ratio, gm/kg
Dry adiabats
Elevation 1000 me
D
C
B
A
E



Isobars, mb
Elevation 1000 meters
Temperature, °C
Saturation adiabats
Saturation mixing ratio, gm/kg
Dry adiabats