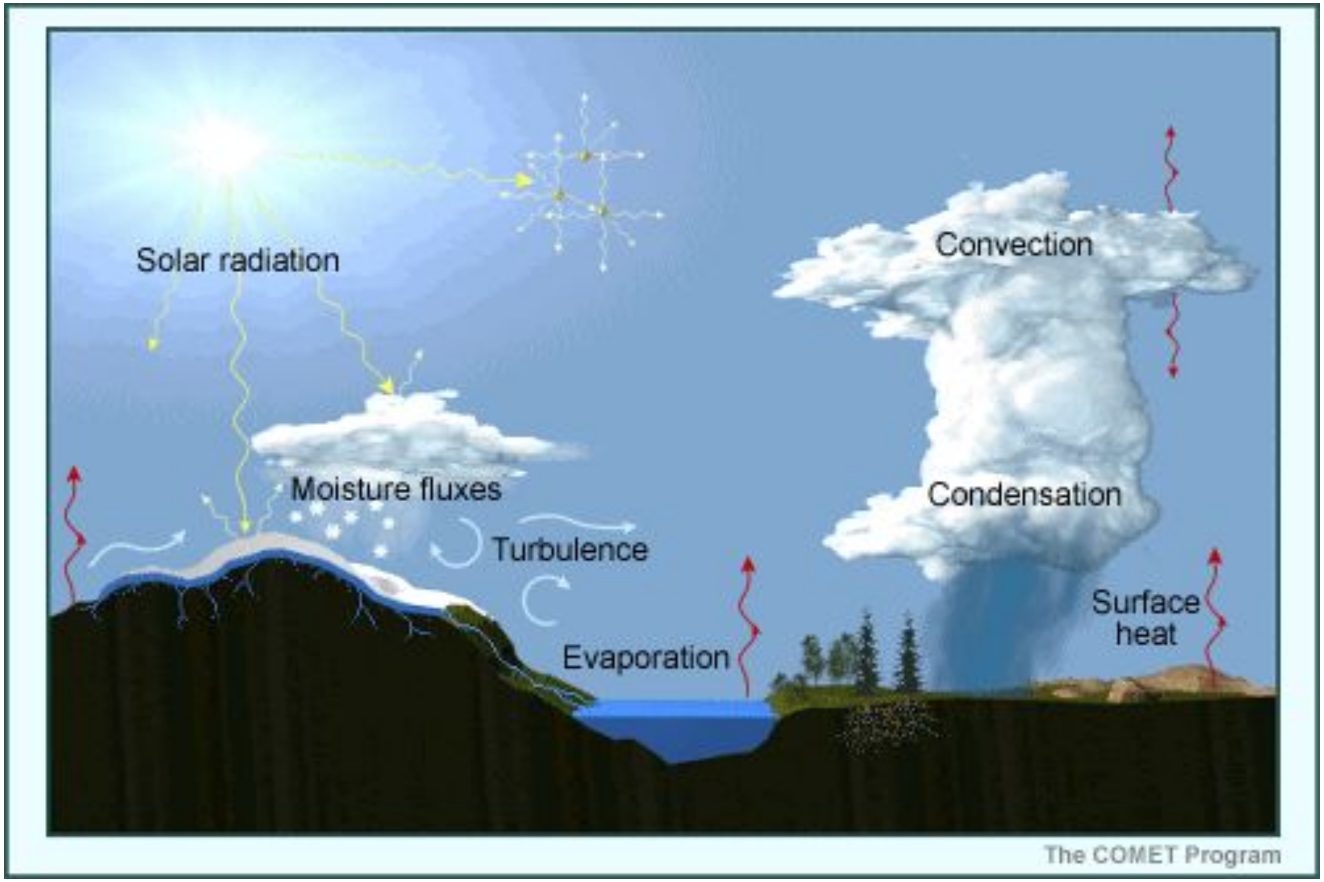
The air humidity

Lecture 20

Memory flash ;)

Please, give definitions to the following terms:

- Absolute humidity
- Specific humidity
- Surface layer
- Boundary layer



How much is the amount of water taking part in this rotation?

http://www.meted.ucar.edu/mesoprim/mesodefn/index.htm

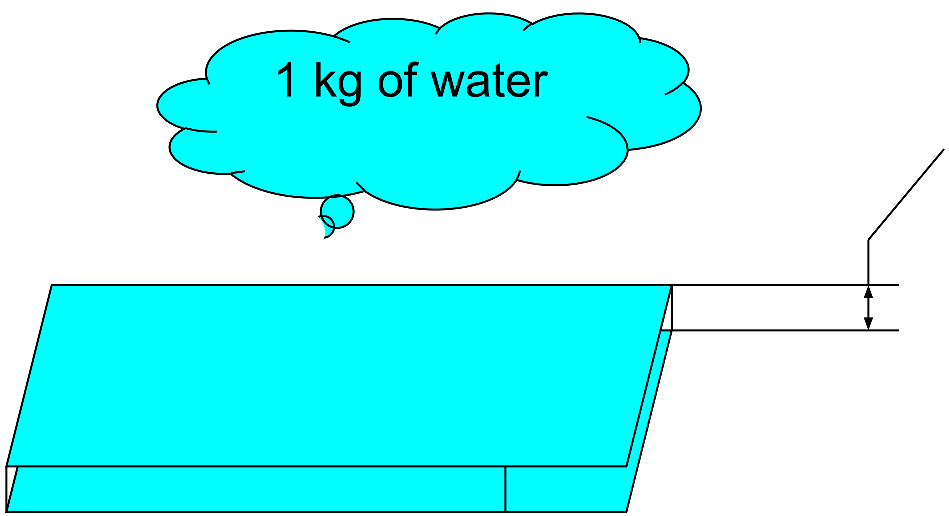
0

Annual means of water amount involved in the atmospheric circulation			
	precipitation mm/year	evaporation mm/year	Run-off mm/year
Lands	689	423	266
Oceans	1313	1423	110
The Globe	1131	1131	0

$1\ m^2$

$1\ m^2 =$ cm^2

Water density = $g/\ cm^3$



What is thickness of water layer?

$1\ 000\ g : 1\ g/cm^3 =$

$= 1\ 000\ cm^3$

$1\ 000\ cm^3 : 10\ 000\ cm^2 =$

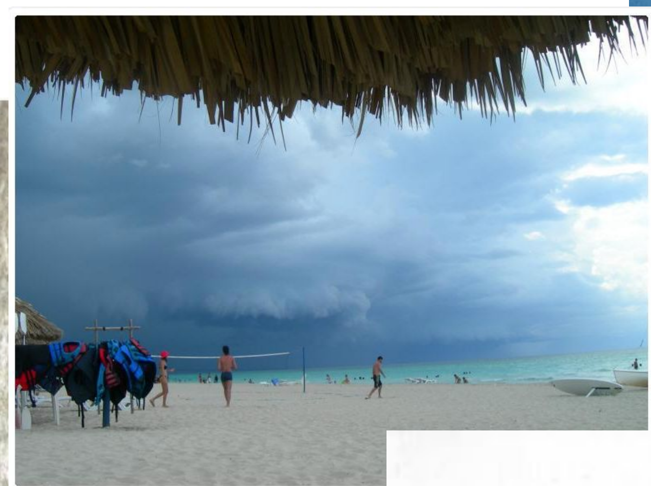
$= 0.1\ cm = 1\ mm$

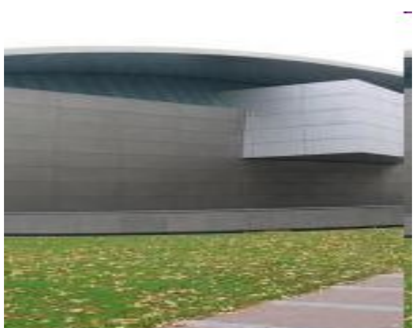
1 kg of water per $1\ m^2$ □ 1 mm of precipitated water

Annual amount of precipitation

Spb 680 mm, Wien 300 mm, Amsterdam 1200 mm

Tropics 680 mm/ day !





- 1.29 *10 ^{13} t of water in the atmosphere (3 phases all together)

1131 / 25.5=45 times or every 8 days

- Equivalent to 25.5 mm
- Annual amount of precipitation is 1131 mm

<u>How often is the water replaced in the atmosphere?</u>

1131 / 25.5=45 times or every 8 days

- To evaporate 1131 mm of water we need 2.82* 10 ^{5} J or 30% of solar radiation absorbed by the planet

Equation of water transfer in the turbulent atmosphere

$$Q_w = -k_w \rho \partial S / \partial z \qquad (20.1)$$

$k_w - eddy\ diffusion\ coefficient, m^2/s$

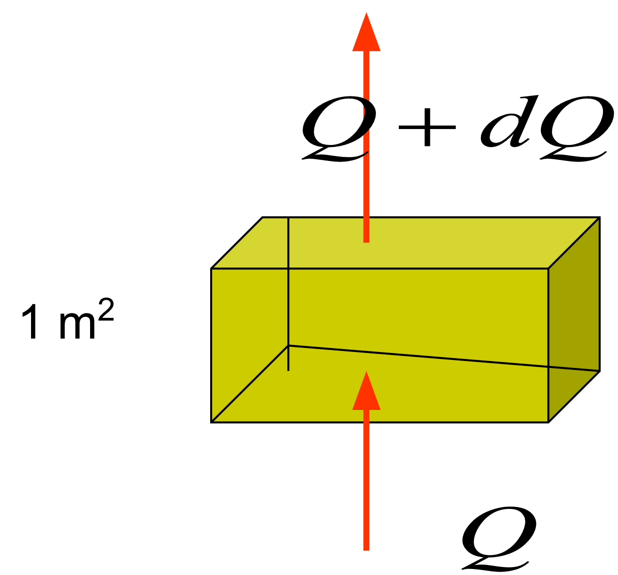
$s - specific\ humidity$

$Q_w - turbulent\ flux\ of\ water\ vapour$

Only specific humidity could be considered as a conservative characteristic of w.v.content of a moving particle (no absolute or relative humidity, dew point, w.v.pressure

Equation of water transfer in the turbulent atmosphere

$$Q-(Q+dQ)=-dQ$$



Amount of the w.v.mass remained in the

air volume per a unit of time

$$-Q=-\partial Q/\partial z\,dz=$$

$$=\partial/\partial z(k\rho\,\partial s/\partial z)\,dz \qquad (20.2)$$

$$\rho \frac{ds}{dt} dz \qquad (20.3)$$

Advective terms could be neglected (too small)

the water vapour mass change

within the air volume

Advective terms could be neglected (too small)

$$-dQ = \rho \frac{ds}{dt} = \frac{\partial}{\partial z}(k\rho\, \partial s / \partial z) +$$

$$+ \frac{\partial}{\partial x}(k' \rho\, \partial s / \partial x) + \frac{\partial}{\partial y}(k' \rho\, \partial s / \partial y) \qquad (20.4)$$

$$\rho(\partial s / \partial t + U\, \partial s / \partial x + V\, \partial s / \partial y + W\, \partial s / \partial z\,) =$$

$$= \partial / \partial z\,(k\rho\, \partial s / \partial z) + \partial / \partial x(k' \rho\, \partial s / \partial x) + \partial / \partial y\,(k' \rho\, \partial s / \partial y)$$

$$\rho(\partial s/\partial t + U\,\partial s/\partial x + V\,\partial s/\partial y + W\,\partial s/\partial z) =$$

Eddy diffusion of w.v.

$$= \partial/\partial z\,(k\rho\,\partial s/\partial z) + \partial/\partial x(k'\rho\,\partial s/\partial x) +$$

$$+ \partial/\partial y\,(k'\rho\,\partial s/\partial y)$$

$$\frac{\partial s}{\partial t} = \frac{1}{\rho}\left[\frac{\partial}{\partial z}(k\rho\,\partial s/\partial z) - (U\,\partial s/\partial x + V\,\partial s/\partial y) - W\,\partial s/\partial z\right] \quad (20.5)$$

in/outflux of w.v. due to evap./condensation

Eddy diffusion of w.v.

Horizontal transfer or advection

Convective w.v. transfer

The equation is true for non-saturated air

Only vertical eddy diffusion is represented here but it could be both vertical and horizontal

Distribution of the humidity characteristics with height in the ***surface layer***

Let’s find S=S(z) in the surface layer integrate (20.5) from 0 to Z

$$\int_0^z \rho \frac{\partial s}{\partial t} dz = \rho k \, \partial s / \partial z - (\rho k \, \partial s / \partial z)_0 -$$

negligibly small comparing to

(20.6)

With the accuracy 10 % : $$\rho k \frac{\partial s}{\partial z} - (\rho k \frac{\partial s}{\partial z})_0 \approx 0 \qquad (20.7)$$

Is the w.v.flux at z=0, i.e. the rate of evaporation from the Earth’s surface:

$$-(\rho k \frac{\partial s}{\partial z})_0 = Q'_0$$

can be regarded as approximately unchangeable with height (as well as a heat flux).

$$\rho k \frac{\partial s}{\partial z} + Q'_0 = 0 \qquad or \qquad Q'_0 = -\rho k \frac{\partial s}{\partial z} \qquad (20.8)$$

Similarly to the heat flux :

(20.8) shows that the w.v. eddy flux in the surface layer can be regarded as approximately unchangeable with height (as well as a heat flux).

Similarly to the heat flux :

$$S(z) = S_2 - \frac{Q'_0}{a\rho_0} \ln \frac{z + z_0}{z_2 + z_0} \qquad (20.9)$$

"*S*" decreases at $Q'_0 < 0$ with height proportionally to *ln z*

Humidity distribution *above the surface layer*

$$\frac{e}{e_0} = \frac{p}{p_0} = \exp\left(-\frac{g}{R}\frac{z}{T_m}\right) \qquad (20.10)$$

Comparision of calculated and observed w.v. pressure values shows that the observed values decrease with height much more rapidly than calculated ones.

$$S = S_0 * 10^{-\frac{z}{g} - \frac{z^2}{120}} \qquad (20.11)$$

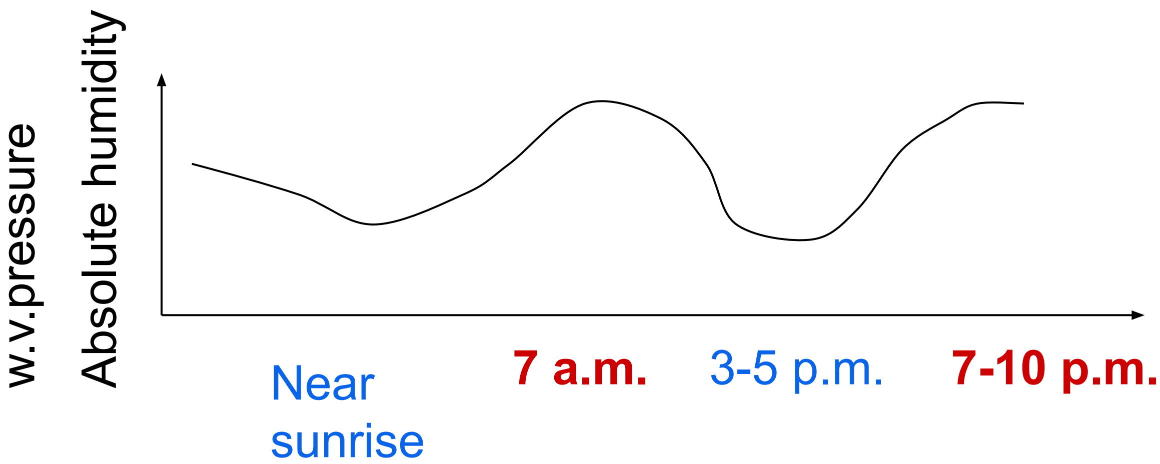
Suring's formula

(empirical)

Z in km

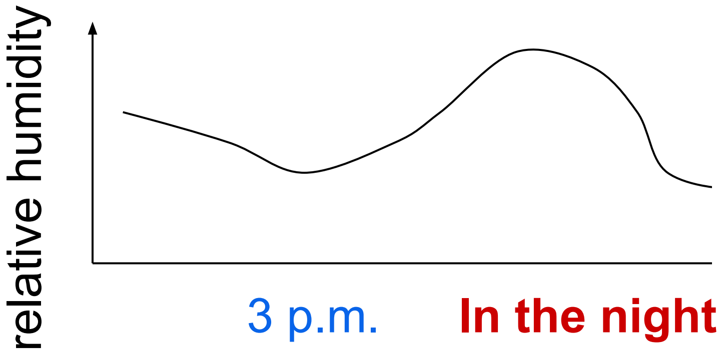
True within the boundary layer above the surface layer

Diurnal variation of the humidity characteristics



Diurnal variation is better pronounced over land in the warm season

Diurnal variation of the humidity characteristics



when T air drops

In winter/over water surfaces:

One min, usually before sunrise.

Weak max, supposed before noon.

Reasons:

1. Eddy exchange is weak
2. Eddy transfer of the w.v. is compensated by evaporation

RH=100% *e/E

e decreases near noon (summer)

E sharply increases (account for *T* rise)