Fast questionnaire

Version 1

1. Give the definition of the solar constant?
2. Write the dimension of the eddy coefficient, please.
3. Write down the humid air state equation and give notions to all terms.
4. What does convection process mean?
5. Write down statics' equation and give notions to all terms.
6. What is the potential temperature?

Version 2

1. What value is higher and why: meteorological or astronomical solar constant?
2. Please, describe the entrainment process briefly.
3. Write down the dry air state equation and give notions to all terms.
4. How do you understand term "convergence"?
5. Please, give numerical form of relation between dry air gaseous constant R and specific heats at const V and p.
6. Write down the potential temperature formula with all notations.

Storm near Elko, Nevada. NOAA

Definition

Water drops and ice crystals falling out
or
any product of the condensation of atmospheric water vapor that is pulled down by gravity and deposited on the Earth's surface
is called
***Precipitation*.**

Amount of precipitation is measured by the thickness of the liquid water layer that could be formed after precipitation fall out on a horizontal surface.

$1\ mm = 1\ kg/m^2$

Hydrometeor

The term meteor describes an object from outer space which has entered the Earth's atmosphere and produces a light phenomenon

The amount of Precipitation falling out per a unit of time is called ***Precipitation intensity***

mm/s (rare),
mm/h (forecasts),
mm/day,
mm/ month (climatologically texts)

Forms of *Precipitation:*

- rain,
- snow,
- ice pellets (шарик,гранула),
- graupel
- dew
- drizzle (r< 0.25 mm)
- sleet

Dew

Liquid drops formed on the surfaces after water vapor condensation against chilled surfaces.

Example:
Over thin blades of grass and leaves at night

In England ***sleet*** is defined as a mixture of rain and snow, or melting snow.

Rain, snow, or ice pellets may fall steadily or in showers. Steady precipitation may be intermittent (перемежающийся) though lacking sudden bursts of intensity.

Hail, small hail, and snow pellets occur only in showers.

Drizzle, snow grains, and ice crystals occur as steady precipitation.

Showers originate from instability clouds of the **cumulus** family, whereas

steady precipitation originates from *stratiform* clouds.

All precipitation types are called hydrometeors, of which additional forms are clouds, fog, wet haze, mist, blowing snow, and spray. Whenever rain or drizzle freezes on contact with the ground to form a solid coating of ice, it is called

- freezing rain,
- freezing drizzle,
- or glazed frost;
- it is also called an ice storm or a glaze storm, and sometimes is popularly known as
- silver thaw (оттепель) or
- erroneously (ошибочно) as a sleet storm.

Duration of precipitation

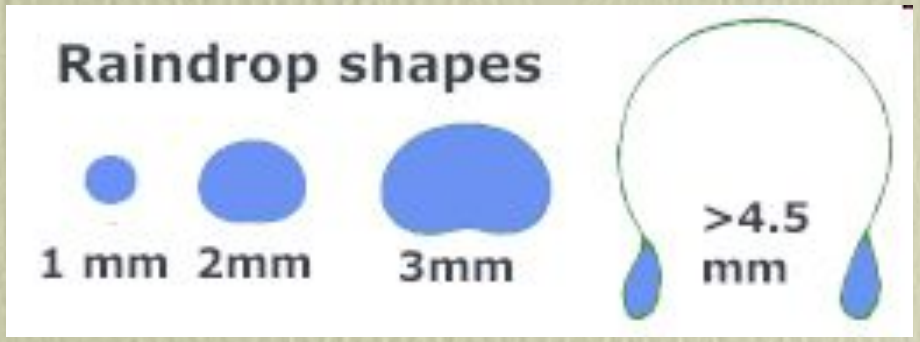
- Brief -Short duration.
- Intermittent -Precipitation which ceases at times.
- Occasional -Precipitation which while not frequent, is recurrent.
- Frequent -Showers occurring regularly and often.
- Continuous -Precipitation which does not cease, or ceases only briefly.
- Periods of rain -Rain is expected to fall most of the times, but there will be breaks.

Distribution of showers and precipitation

- Few- Indicating timing and not area.
- Isolated -Showers which are well separated in space during a given period.
- Local -Restricted to relatively small areas.
- Patchy- Occurring irregularly distributed over an area.
- Scattered-Irregularly distributed over an area. Showers, which while not widespread, can occur anywhere in an area. Implies a slightly greater incidence than isolated.
- Widespread -Occurring extensively throughout an area.

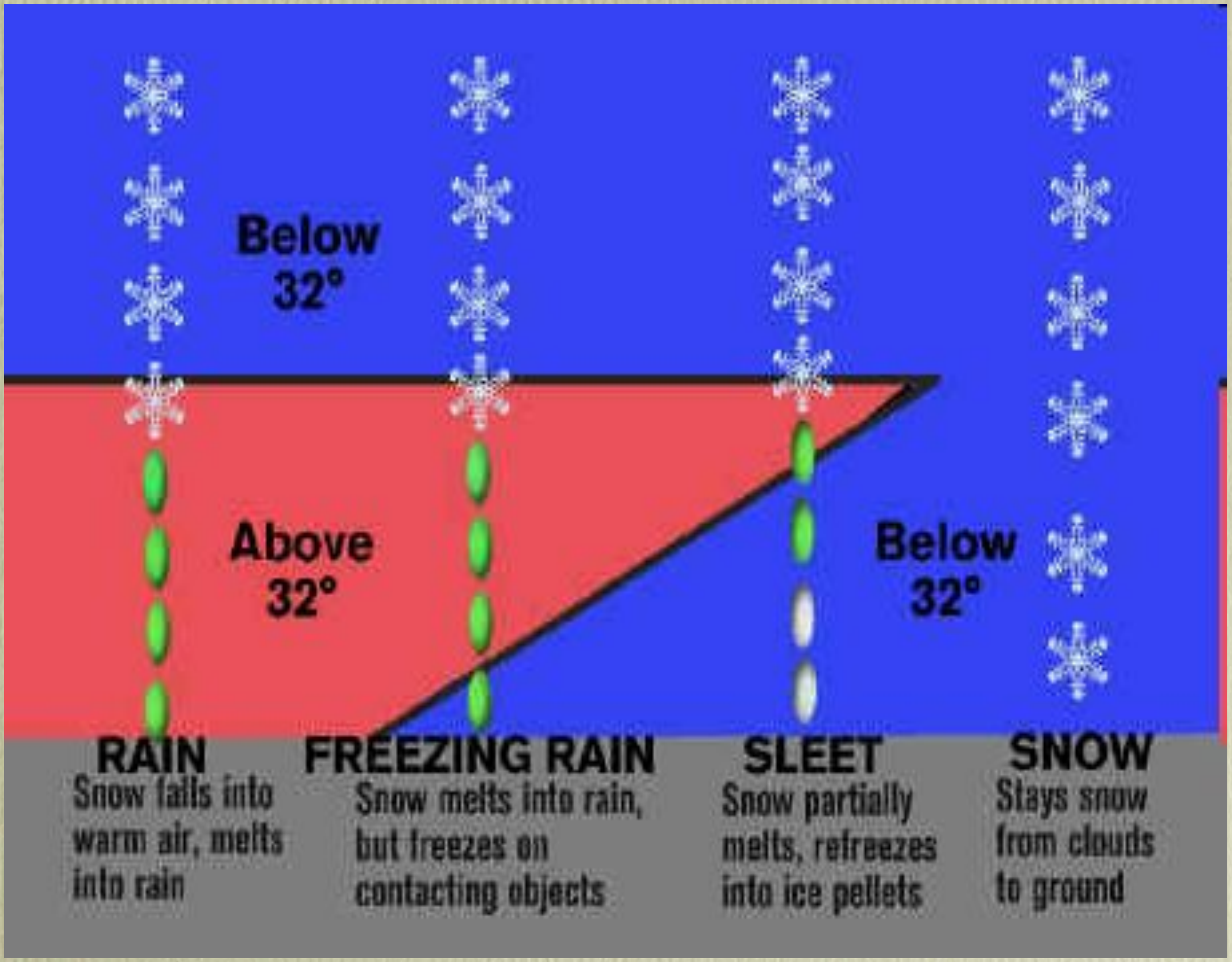
Can you guess the shape of raindrops?

They are actually shaped like hamburgers! As they fall, the air pushes on the bottoms of the drops, causing the bottoms to flatten out while the tops remain round.



http://www.wxdude.com/page3.html

http://ga.water.usgs.gov/edu/watercycleprecipitation.html



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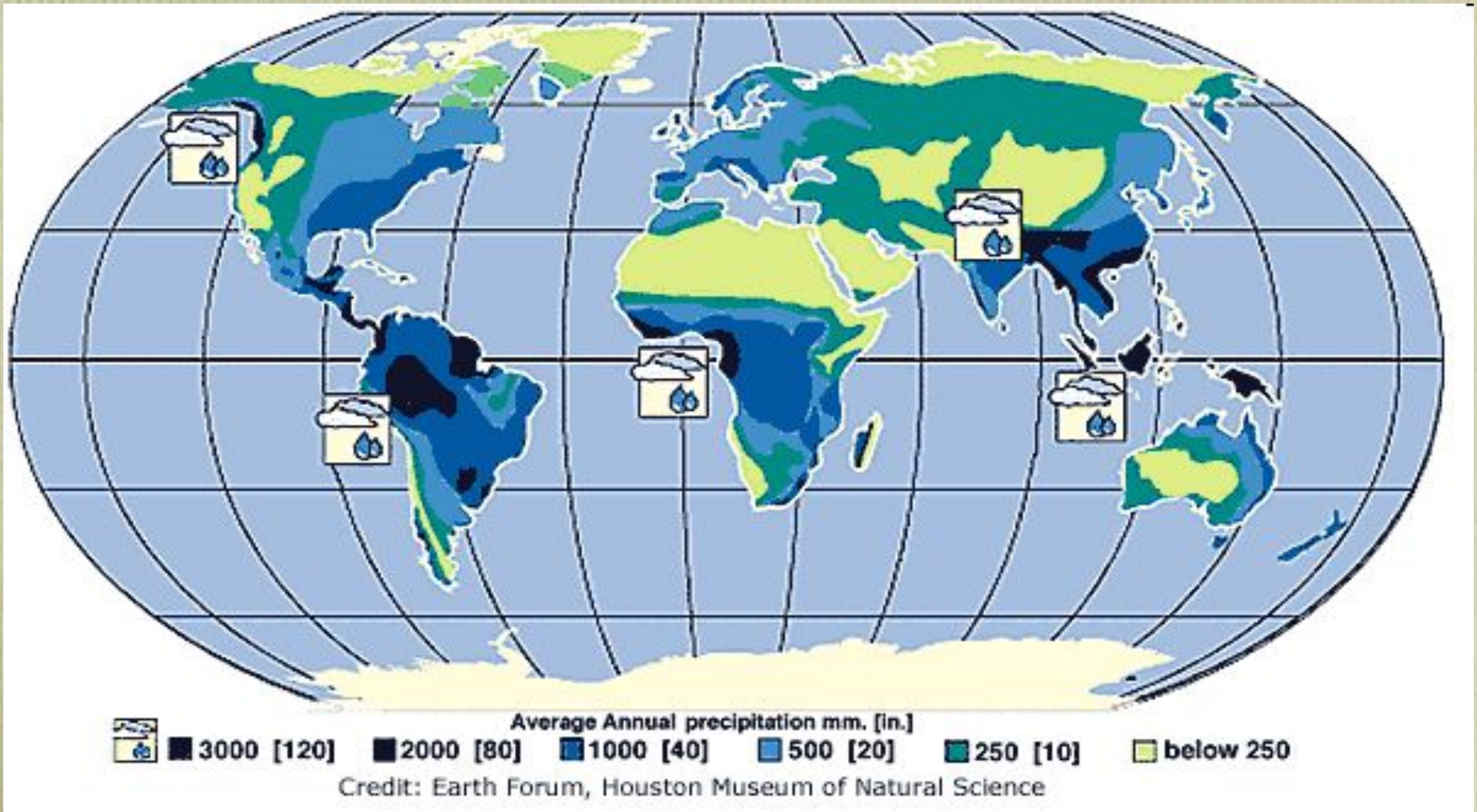
Cloud thickness, m	850	1400	2150	2300	2600	3150
precipitation	drizzle	Rain with drizzle	rain	snow	sleet	Rain after ice particle melting

1- avearge values of cloud thickness
2- downpour precipitation is not included

Precipitation rates vary geographically and over time



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Precipitation size and speed

	Intensity inches/hour (cm/hour)	Median diameter (millimeters)	Velocity of fall feet/second (meters/second)	Drops per second per square foot (square meter)
Fog	0.005 (0.013)	0.01	0.01 (0.003)	6,264,000 (67,425,000)
Mist	.002 (.005)	.1	.7 (.21)	2,510 (27,000)
Drizzle	.01 (.025)	.96	13.5 (4.1)	14(151)
Light rain	.04 (1.02)	1.24	15.7 (4.8)	26 (280)
Moderate rain	.15 (.38)	1.60	18.7 (5.7)	46 (495)
Heavy rain	.60 (1.52)	2.05	22.0 (76.)	46 (495)
Excessive rain	1.60 (4.06)	2.40	24.0 (7.3)	76 (818)
Cloudburst	4.00 (10.2)	2.85	25.9 (7.9)	113 (1,220)

Virga

http://en.wikipedia.org/wiki/Virga

In meteorology, virga is an observable streak or shaft of precipitation that falls from a cloud but evaporates before reaching the ground.

At high altitudes the precipitation falls mainly as ice crystals before melting and finally evaporating; this is usually due to compressional heating, because the air pressure increases closer to the ground.

It is very common in the desert and in temperate climates.

Virga

http://en.wikipedia.org/wiki/Virga

Virga can cause varying weather effects, because as rain is changed from liquid to vapor form, it removes heat from the air due to the high heat of vaporization of water.
In some instances, these pockets of colder air can descend rapidly, creating a dry microburst which can be extremely hazardous to aviation. Conversely, precipitation evaporating at high altitude can compressionally heat as it falls, and result in a gusty downburst which may substantially and rapidly warm the surface temperature. This fairly rare phenomenon, a heat burst, also tends to be of exceedingly dry air.

Virga also has a role in seeding storm cells whereby small particles from one cloud are blown into neighboring supersaturated air and act as nucleation particles for the next thunderhead cloud to begin forming
Virga can produce dramatic and beautiful scenes, especially during a red sunset. The red light can be caught by the streamers of falling precipitation, and winds may push the bottom ends of the virga so it falls at an angle, making the clouds appear to have commas attached.

Virga

http://en.wikipedia.org/wiki/Virga

The word virga is derived from Latin, twig or branch. A backronym sometimes found in amateur discussions of meteorology is "Variable Intensity Rain Gradient Aloft."

Extraterrestrial occurrences

Sulfuric acid rain in the atmosphere of Venus evaporates before reaching the ground due to the high heat near the surface. Similarly, virga happens on gas giant planets such as Jupiter. In September 2008 NASA's Phoenix lander discovered a snow variety of virga falling from Martian clouds.

Virga

http://en.wikipedia.org/wiki/Virga

Processes of cloud element enlargement and precipitation formation

1- w.v. supersaturation with respect to cloud droplet surface

2- **w.v. condensation process**

3- if ice crystal appears distillation

4- **coalescence /coagulation** begins as droplet

r= 20…60 micrometers

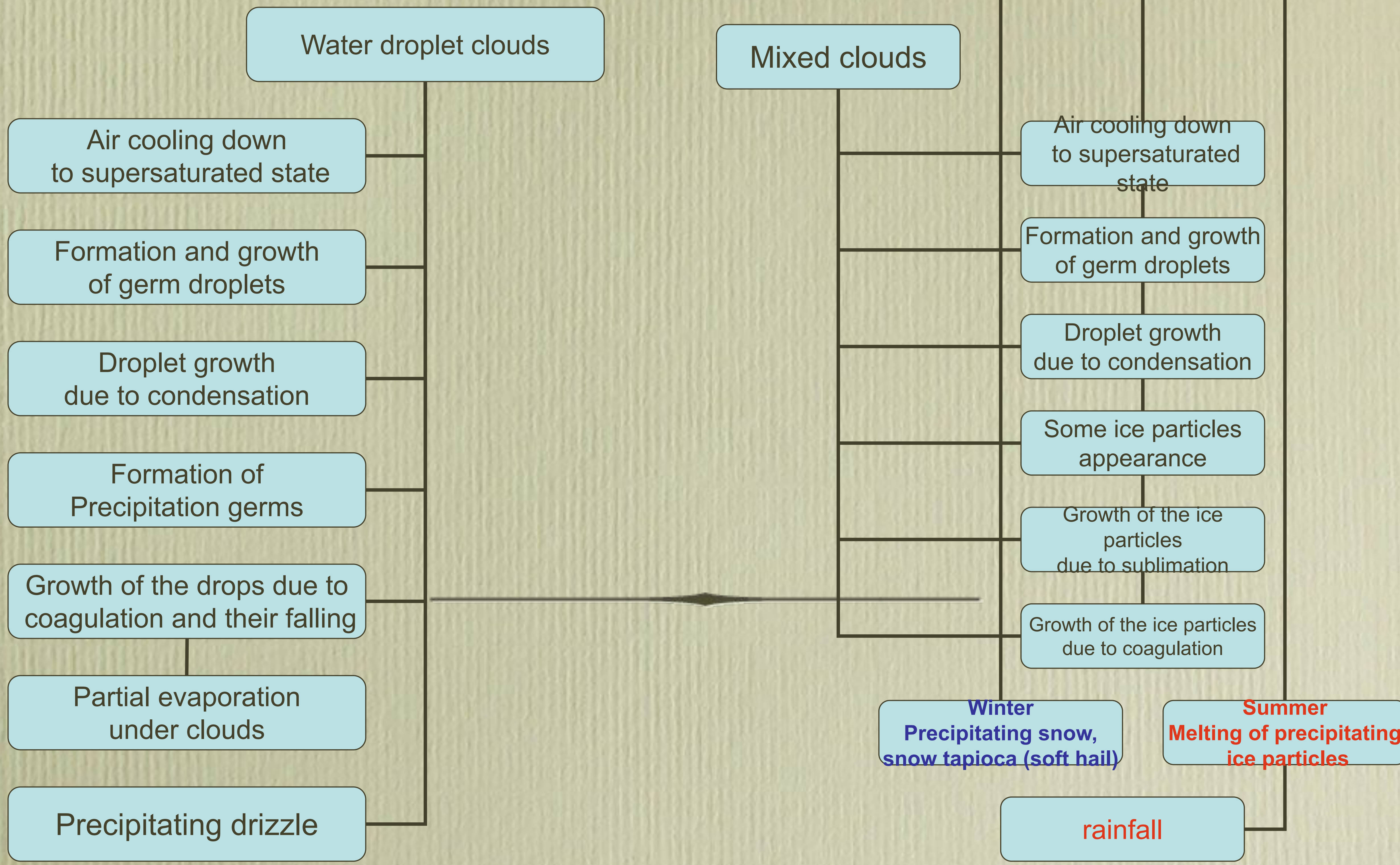
result of different downward W) **gravitational coagulation;**

eddy and Brownian movements **… coagulation;**

Coagulation
rain drop, ice crystal grow up to few mm,
snowflakes, hailstones –up to few cm

Rate of droplet enlargement due to coagulation ~ r
Rate of droplet enlargement due to condensation ~ 1/r

Precipitation from stratiform clouds. Scheme of formation



The rate of fall for solid and liquid particles in the atmosphere

Atm. Particle is affected by:

- external forces [redacted]
- [redacted]
- [redacted]

According to the 2 nd Newton's law

$$m\frac{d\vec{V}}{dt} = \vec{F} + \vec{G} \qquad (26.1)$$

$\vec{V}$ *is a particle velocity*

$\vec{F}$ *is a resistance force,* $\sim V, r, \ldots$

$\vec{G}$ *is an external force (ex., gravity)*

According to Stocks law for ball like particles

$$\vec{F}_0 = -6\pi\eta r\vec{V} \qquad (26.2)$$

η *is a molecular viscosity coefficient*

r *is a particle radius*

"0" *indicates ball like particle*

(26.2) is valid for low Reynolds number Re*<3

According to experiments

$$\vec{F} = \vec{F}_0\,(1+\frac{1}{6}\mathrm{Re}^{2/3}) \qquad (26.3)$$

(26.3) is correct for 3 < Re < 400

dimensionless numberdimensionless number, gives a measure of the ratiodimensionless number, gives a measure of the ratio of inertial forcesdimensionless number, gives a measure of the ratio of inertial forces to viscous forces and consequently quantifies the relative importance of these two types of forces for given flow conditions.

$$\mathrm{Re} = \frac{\rho V L}{\mu} = \frac{V L}{\nu}$$

- V is the mean velocity of the object relative to the fluid (SI units: m/s)
- *L* is a characteristic linear dimension, (travelled length of the fluid; hydraulic diameter when dealing with river systems) (m)
- μ is the dynamic viscosityμ is the dynamic viscosity of the fluid (Pa·s or N·s/m² or kg/(m·s))
- ν is the kinematic viscosity (ν = μ / ρ) (m²/s)
- ρ is the density of the fluid (kg/m³)

laminar flow occurs at low Reynolds numbers, where viscous forces are dominant, and is characterized by smooth, constant fluid motion; while *turbulent flow* occurs at high Reynolds numbers and is dominated by inertial forces, which tend to produce chaotic eddies occurs at high Reynolds numbers and is dominated by inertial forces, which tend to produce chaotic eddies, vortices and other flow instabilities.

Ball-like particle fall under influence of gravity, small Re

External force= gravity + buoyancy forces

$$G = \frac{4}{3}\pi r^3 \rho_d g - \frac{4}{3}\pi r^3 \rho\ g \qquad (26.4)$$

Acting downward acting upward air density

$$G = \frac{4}{3}\pi r^3 g(\rho_d - \rho)$$

$$G = \frac{4}{3}\pi r^3 \rho_d g \quad \textit{due to} \quad \rho << \rho_d \qquad (26.5)$$

$$\rho_{ice\ particle} = 960\ kg/m^3, \quad \rho_d = 1000\ kg/m^3, \ \rho = 1.29\ kg/m^3$$

Owing to the fact that F and G are directed along vertical line,
Using (26.2) and (26.5) :

$$m\frac{dV}{dt} = \frac{4}{3}\pi r^3 \rho_d g - 6\pi\eta r V \qquad (26.6)$$

V is positive when it is directed downward.

(26.6) *can be presented in form*

$$\frac{dV}{dt} + \frac{V}{\tau} - g = 0 \qquad (26.7)$$

τ *is time of relaxation*

$$\tau = \frac{m}{6\pi\eta r} = 2r^2\rho_d / 9\eta$$

Steady state motion dV/dt=0

V_s is a speed of steady state motion

$$V_s = g\tau \quad or \quad V_s = \frac{2g\rho_d}{9\eta} r^2 \qquad (26.8)$$

$$it\ is\ Stokes'\ formula, works\ when\ r = 10^{-5} ... 5*10^{-3}\ cm$$

So, $V_s \sim r^2$ at small Re (or small r)

Unsteady motion dV/dt ≠ 0

 let's use an eq-on of the particle motion

$$\frac{dV}{dt}+\frac{V}{\tau}-g=0 \qquad (26.9)$$

initial moment of a particle falling

$t_0 \; ,V_0$

$$solution \;\; of \;\; (26.9) \rightarrow V = V_0 \exp(-t/\tau) \qquad (26.10)$$

Since V=dx/dt, after integrating (26.10)

$$V = V_0\tau(1-\exp(-t/\tau)) \qquad (26.11)$$

At t=*τ* V ↓ in *e* times as compared with V_0 physical meaning of relaxation time

Assuming

$$\tau = \infty \rightarrow \max imal\ \ dis \tan ce\ L_i\ particle\ \ passes$$

$$through\ in\ a\ resis \tan t\ environment$$

$$having\ initial\ speed\ V_0$$

$$L_i = V_0 \tau = \frac{2 V_0 r^2 \rho_d}{9\eta} \qquad (26.12)$$

$$inertial\ path\ of\ the\ particle\ run\ L_i$$

All above is true for *ball-like* particle

As droplet reaches r=> 0.5 mm deformations

Non ball-like particle speed is determined empirically:

$$accuracy\ about\ 3.7\%$$

$$V_s = 8.03*10^{-3} r_e + 0.013 \quad at \quad 200\mu < r_e < 500\mu$$

$$V_s = 3.67*10^{-10} r^3{}_e - 3.27*10^{-6} r^3{}_e + 9.57*10^{-3} r_e + 0.121 \quad at \quad r_e > 500\mu$$

r_e *is equivalent drop radius*

(*the drop would have if it were ball – like at its real volume*)

V_s *in* m/s