



Tananyag fejlesztés idegen nyelven

Prevention of the atmosphere

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Physical basis of weather- contamination interaction (advection)

Lecture 3
Lessons 7-9



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Lesson 7

Air motion types with their impacts (some examples)



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Relationship between the atmosphere and environmental (atmospheric) pollution

The most important elements of the titled connection

1. *Air motions*
2. *Air (ambient) temperature*
3. *Air pressure systems*

The weather of a given geographical place means a very complex event owing a lot of determinants. They are present together, satisfying the complexity of the phenomenon. The weather element's separation may only be on academic level! In reality never.





1. Different types of air motion

a) *Laminar flow- turbulent flow and Reynolds number**

Laminar flow appears when viscous forces are dominant, and ***smooth, constant motion*** is forming.

Turbulent flow used to be at high Reynolds numbers dominated by inertial forces. Random eddies are produced with ***high flow instabilities***.

*a measure of the ration of inertial forces to viscous forces. It quantifies the relative importance of the two forces for the determined flow conditions



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Flow types

Laminar flow – they would be just above homogenous surfaces (above oceans or seas). But the Earth rotation and surface friction disturbs the parallel flow lines and eddies are produced. Due to Earth rotation and surface friction, in the atmosphere the laminar flow is not a frequent phenomenon

Turbulent flow – above heterogeneous surfaces the energy and mass transfer are taken place by eddies. Here the flow lines are not parallel as in case of laminar flows.





Fig. 18 The smoke and the eddies cause dilution of smoke particles

The turbulent air motion causes more efficient property exchange.

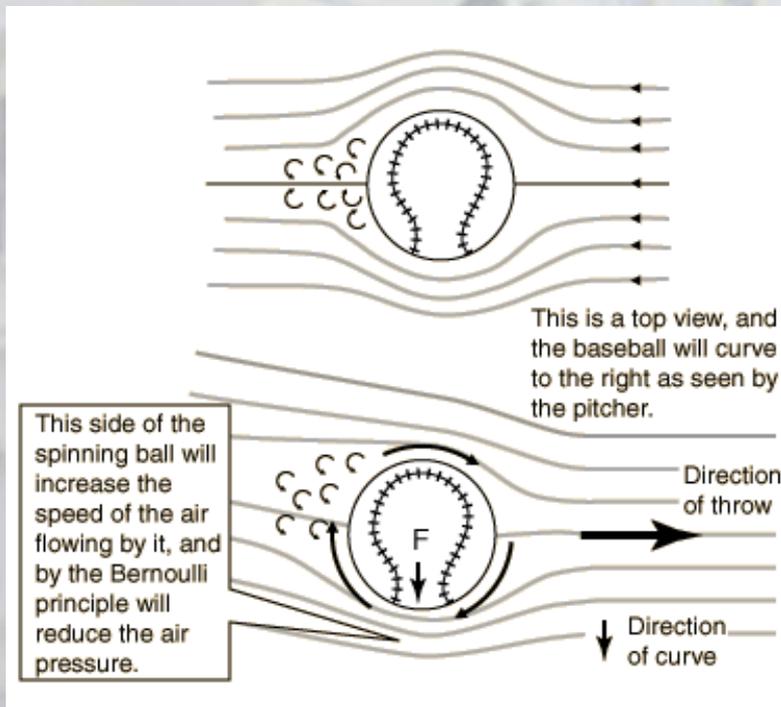
In the atmosphere the turbulence is a dominant air characteristic.

www.colbycosh.com/mt/2007/11.html



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Fig. 19 A practical sample to show the impact of eddies around a not smooth ball



The air flow around a smooth ball is different than the air flow around a ball with stitches (**turbulence** can be found around the stitches)

The second part of the chart contains the throw direction also

Fig. 20 The turbulent flow after NASA website photo:



The laminar flow trajectories are around the ball, the eddies can be found before it

boojum.as.arizona.edu/.../turbulent.html



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Our second sample: an air cleaner work by using the turbulent flow properties

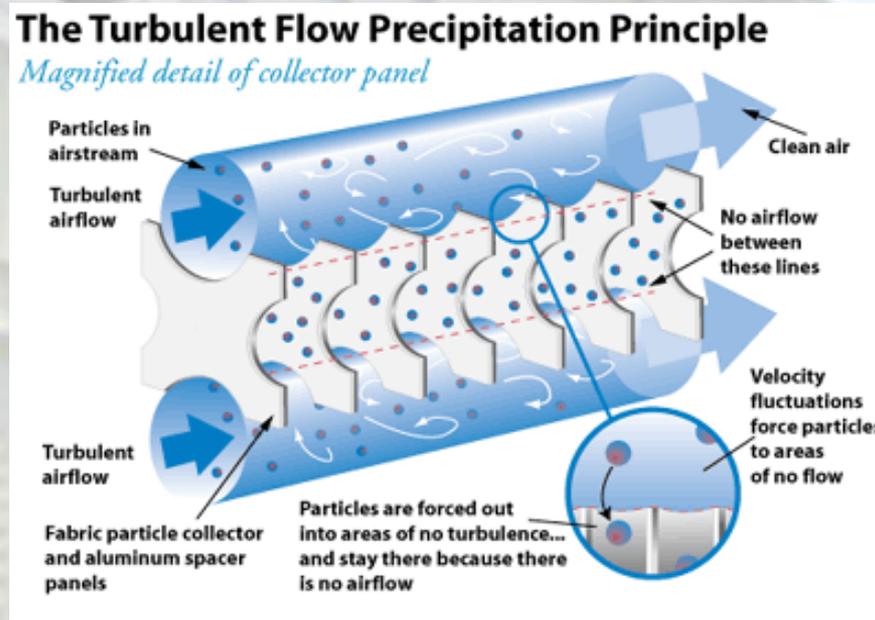
Device (see next Fig.): removes almost 100% of particles
as pollen, fungus spores, dust, animal dander;
90% of tobacco and wood smoke particles, bacteria; and
small sized particles (also below $0.1 \mu\text{m}$)

The process is governed by turbulent flow and there is no
need of any filter

But how does it function?



Fig. 21 Air cleaner – with turbulent flow



- www.healthyhouseinstitute.com/t_257-Air_Clean...



The principle of cleaner is as follows:

- The walls of the internal airway (dirty air pass) are made of a pleated fabric and traps particles as they are flung out of the airstream
- Cleaning takes places without conventional filters to obstruct the flow of air
- No need of filters, no necessity of cleaning them, because there are no filters included! The only reason of work is the turbulent air flow





b) Air motion groups on the basis of direction of air, in connection to air contamination

- **Advection** – the so called „wind”, a special property exchange. It can also produce energy or mass transfer
- **Convection** - vertical air motion induced by different levels of surface warming.
- ***Turbulent diffusion*** – independent on air motion. The reason of placing here is due to its final production; this is the mixing of the atmosphere of a given layer





Lesson 8

The advection – global and local level.
Forces of forming the advection I.
Pressure gradient force



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Definition of the advection

- Advection in environmental studies including meteorology means the horizontal transfer of heat or other atmospheric properties . The transport of air masses* (warm air, moist air etc.) with different characteristics
- Advection in atmospheric pollution means transport of different contaminants by the wind. Final effect may be positive (dilution) or negative (carrying pollutant by the wind to such places, where there are no emission sources)

* air mass: large, or widespread, body of air of fairly uniform features



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Types of advection

The horizontal air motion takes place on two different levels of varying physical and other characteristics.

If the air motion associated with a widely extended and constant wind means a **global level** phenomenon.

Globally the air motion is always structured. Our example is the Earth Global Circulation pattern. It contains the constant characteristics of air movement in both space and time.

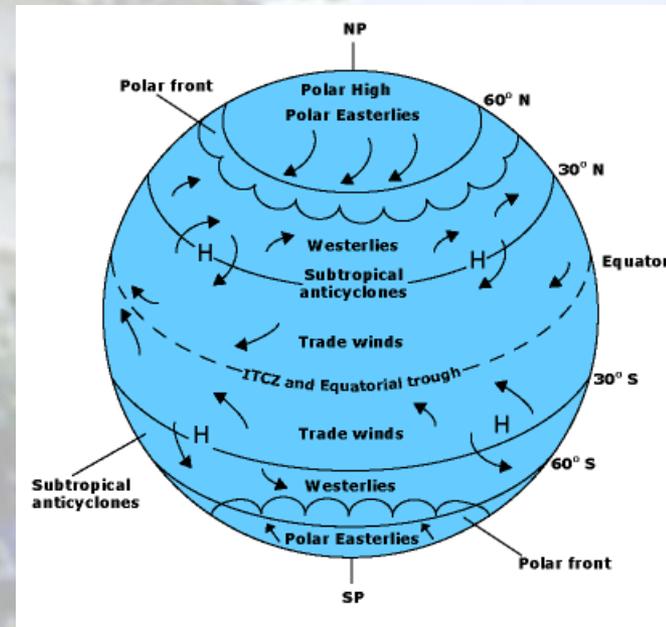
In a given moment and at different geographical places the wind speed and direction may be completely different than the given pattern.



Fig. 22 The Global Circulation Pattern of the Earth

Although the main global winds can not be at every place of the planet, they occupy a larger belt. Three of them have of primary importance

- Trades - on the tropics (E)
- Westerlies – on the temperate climate
- Polar easterlies – close to the poles



nsidc.org/arcticmet/factors/winds.html



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- The second category contains the **local winds**. They blow for a shorter time and touch on a much smaller area than that of the global winds. The reason of local wind formation is the geographical and topographical differences of the Earth surface. There are some famous local winds in Europe as mistral (France/Italy-Mediterranean areas), sirocco (Spain), bora (around the Adriatic sea)
- The local wind on their areas may predominant the global ones.





The most important reasons of local wind formation are, see the next Fig. also!

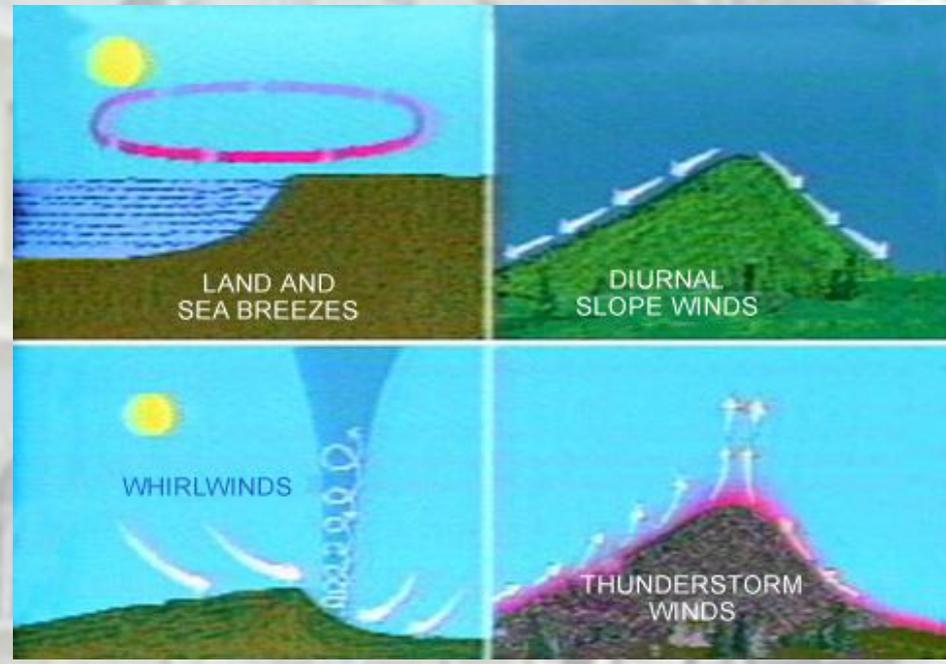
- Convection processes originating from high radiation. This induces the daytime heating (around solar noon is the most intense)
 - Due to surface heterogeneity, the unequal heating and cooling of the surface
 - Gravity, including downdrafts

Projection of local winds used to be successful



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Fig. 23 Four locations forming local winds



[ocw.usu.edu/Forest Range and Wildlife Scien](http://ocw.usu.edu/Forest_Range_and_Wildlife_Scien)



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Forces of forming advection

We are looking the force F written by Newton' s 2nd law. In this law the force moves with an a acceleration of a given body mass, m :

$$F = m a$$

a)The first force is the pressure gradient force (P_x) that should be written in all the three space directions, x , y , z . The x directed component member will be

$$P_x = - \frac{1}{\rho} \frac{dp}{dx}$$

where p is the air pressure
 ρ is the density of the air





The remaining two directions are the y and z components, they should be written on a similar way as x had been.

The force – that is equal to p now - in any place of a vertical column (z) of the atmosphere will be the multiplication of air density and gravitation

$$p = \int_z^{\infty} \rho g dz$$

From this may be expressed the vertical change of p

$$-\frac{dp}{dz} = \rho g$$





It is obvious from the last equation that the air pressure (p) is declining with increasing altitudes (z). The size of change depends on air density and gravitation (g) only.

As we know the relationship between the state variables, applying the air density (ρ), the air temperature (T), as an easily measurable member, it may be expressed and substituted. Not going to the details, finally the barometric formula (exponential atmosphere), the air pressure in the z level is

$$p_z = p_o \exp\left(-\int_0^z \frac{g dz}{RT}\right)$$

Where p_o is the air pressure at the sea level

R is the specific gas constant



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Table 5 The vertical distribution of the most important physical air properties*

Subscript <i>b</i>	Height above sea level		Static pressure		Standard temperature	Temperature lapse rate	
	(m)	(ft)	(pascals)	(inHg)	(K)	(K/m)	(K/ft)
0	0	0	101325	29.92126	288.15	-0.0065	-0.0019812
1	11,000	36,089	22632.1	6.683245	216.65	0.0	0.0
2	20,000	65,617	5474.89	1.616734	216.65	0.001	0.0003048
3	32,000	104,987	868.019	0.2563258	228.65	0.0028	0.00085344
4	47,000	154,199	110.906	0.0327506	270.65	0.0	0.0
5	51,000	167,323	66.9389	0.01976704	270.65	-0.0028	-0.00085344
6	71,000	232,940	3.95642	0.00116833	214.65	-0.002	-0.0006096

* http://en.wikipedia.org/wiki/Barometric_formula



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Lesson 9

Forces of forming the advection II. Coriolis force. Gravitational force. The equation of air motion



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b) Coriolis force (or effect), E_c

As a results of the Earth's rotation an apparent force, the "Coriolis force" is present, that deflects the wind to the right from the initial direction (Northern Hemisphere) and to the left from the starting direction (Southern Hemisphere). Sometimes this event is called as Coriolis effect.

Determining factors of the Coriolis force are

- The most important factor in deflection magnitude is the latitude, φ , the geographical position on the planet. The force is equal to zero on the Equator, and it shows an increasing level to the direction of the poles.



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- The second factor is the wind speed (u); the higher the deflection, the more strengthen the wind speed is.

There is a special situation where the pressure gradient force and the Coriolis force are balanced. Here the absence of surface friction can be observed, and air flows parallel to isobars. This forms the so called geostrophic wind.

The complete equation to calculate the Coriolis force will be

$$E_c = -2u\Omega \sin \varphi$$

Where Ω is the Earth rotation speed



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Fig. 24 The geostrophic wind (purple colored arrow). Designation L has of meaning of low, and H of high air pressure

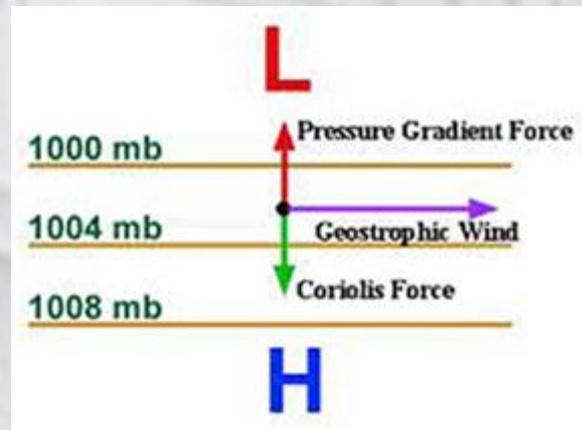
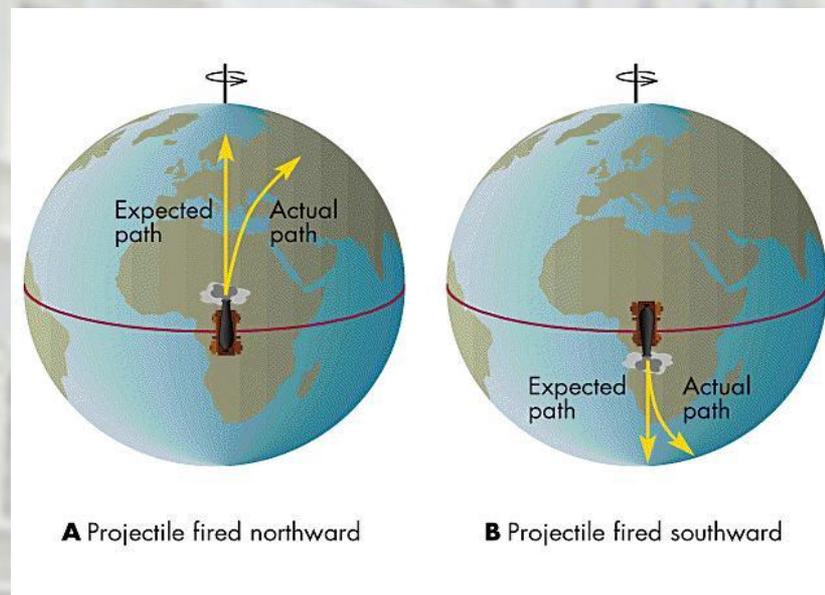


Fig. 25 Wind direction deflection in the two Hemispheres. The arrow shows the direction of Earth rotation



<http://termtud.akg.hu/okt/8/2/Coriolis4.gif>



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- The circulation patterns of cyclone and anticyclone can be discussed by knowing the Coriolis force. This force turns the flow direction as opposed blowing of the pressure gradient.
- The Coriolis effect causes cyclonic systems to turn towards the poles in the absence of strong steering currents.

Fig. 26 Cyclone Monica on Southern Hemisphere shows clockwise rotation due to Coriolis force

(http://en.wikipedia.org/wiki/Tropical_cyclone
#Coriolis_effect)

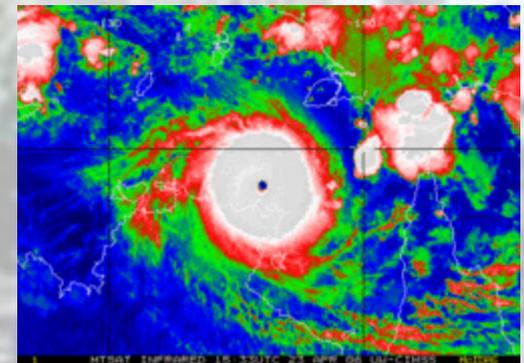
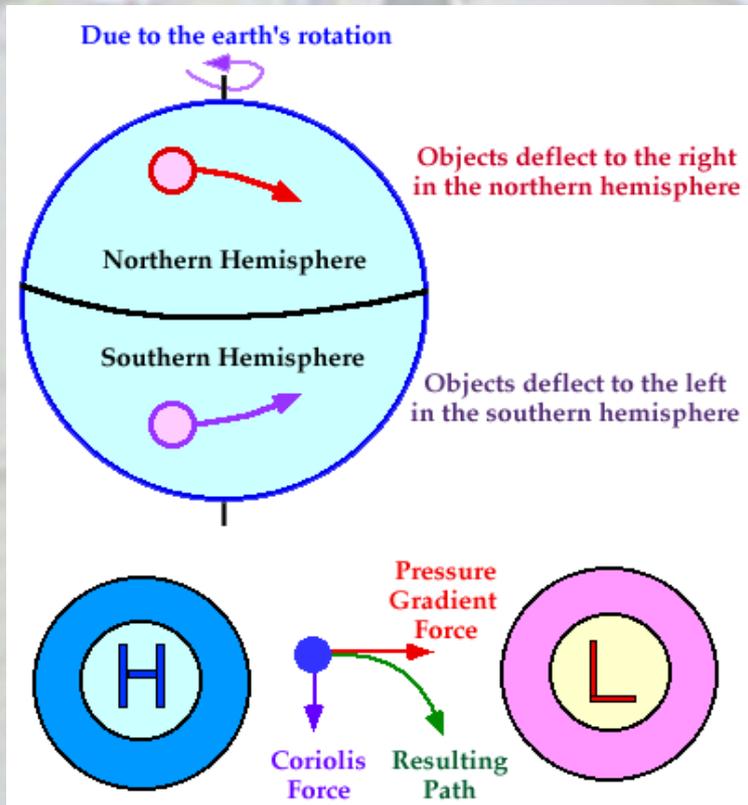


Fig. 27 The scheme of Coriolis effect.

First part of graph contains the deflection impact on the two spheres, and the last row the same to pressure systems (anticyclone,H and cyclone,L)



earthsci.org/flooding/unit1/u1-08-00.html



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c) The friction force, S

If the wind is blowing close to the surface, its flow starts to become less straight. The wind has to move through and around of different objects located on the surface of Earth. On its way the wind may loose or gain in strength. The wind speed varies from time to time depending on the characteristics of the surface.

At lower elevations the friction force can not be neglected. In this areas, the wind has a component, pointing toward the lower atmospheric pressure and, oppositely, away from the higher air pressure.



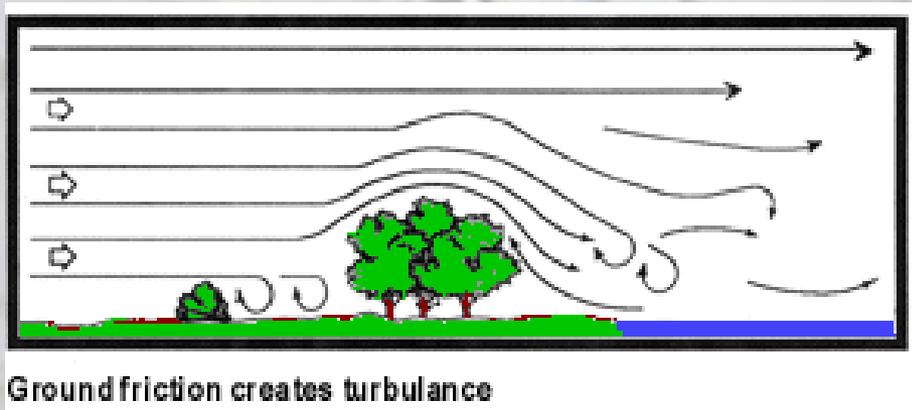


- The layer in the atmosphere, where the surface roughness has a braking impact to the air motion is the atmospheric boundary layer. Above this layer the friction is negligible, and the pressure gradient force and the Coriolis force are in balance, see also earlier in the geostrophic wind function.
- At lower elevations the friction force has of primary importance in determination the air motion (wind speed)



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Fig. 28 Impact of surface roughness on the air motion



www.eso.org/gen-fac/pubs/astclim/papers/lz.../node16.html

The roughness of the surface results heavily oscillating wind patterns in both:

- wind speed and
- wind directions



- The sign (direction) of the friction force is just the opposite as was observed in pressure gradient and Coriolis forces. The reason is the hindering effect of surface roughness.

In average wind conditions the friction force develops in the lowest 1000 m (roughness layer)

The plainer the Earth surface, the faster the wind speed is. Above the plains the lack of objects, obstacles the air motion and heavy wind speed manifests. Where there are landmarks, the wind speed will decline, the atmosphere will be more quite (town with high buildings).





d) Gravitational force, g

- This force arises between all masses in the universe, mainly in the Earth near to its surface.

"The gravitation between two bodies is proportional to the product of their masses and inversely proportional to the square of the distance between them" (Albert Einstein)

For a unit mass of air the connection of $F = g$ is true.

The average g (on sea level, 45° latitude) is 9.80616 ms^{-2}

The exact values of gravitational forces are variable. Its size depends on geographical position on the Earth.

The minimum value can be found at the Equator.

Towards the poles the size of force is increasing



Force of gravity

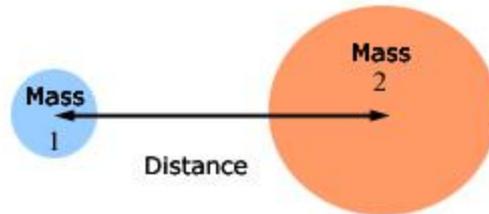
Longhand:

$$\text{Force of gravity} = \text{Gravitational constant} \times \frac{\text{Mass}_1 \times \text{Mass}_2}{\text{Distance}^2}$$

Shorthand:

$$F_g = G \times \frac{m_1 \times m_2}{D^2}$$

Picture:



M. Yasuda 2002

Fig. 29 Scheme of the force of gravity

(www.williamsclass.com/EighthScienceWork/Astro...)



The equation of air motion (for advection)

- Summing the earlier forces the air motion equation for u wind speed vector will be derived (du/dt):

$$\frac{du}{dt} = -P_x - E_c + S - g$$

where P_x : pressure gradient force

E_c : Coriolis force

S : friction force

g : gravitational force



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Importance of advection in transport of pollutants:

Advection in the air means a transport of air from one place to another one.

- a) Advection removes the pollutants to a distance from the source
- b) Advection acts to dilute the pollutants
- c) Advection is the process responsible for the **long-range transport** of pollutants downwind from sources





Debrecen Egyetem
Mezőgazdaság- Élelmiszertudományi és
Környezetgazdálkodási Kar



Pannon Egyetem
Georgikon Kar



Thank you for attention!



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