



Tananyag fejlesztés idegen nyelven

Prevention of the atmosphere

KÖRNYEZETGAZDÁLKODÁSI
AGRÁRMÉRNÖKI MSC
(MSc IN AGRO-ENVIRONMENTAL
STUDIES)



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg



Physical basis of weather- contamination interaction (from convection)

Lecture 4
Lessons 10-12



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg



Lesson 10

The convection. Types and influence on the environmental processes. Turbulent diffusion



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg



The 2nd type of air motion is the convection

A way of heat transfer is the convection, that in the air is joined to vertical air motion.

As the air is not a good energy conductor, the convection is the most important process of Earth energy transport. In the air, the warm surface is in contact to lower thin air layer –only of a few mm- and is warming by conduction.

The warmer air is less dense than colder air, and rises upward as bubbles of warm air. The event is governed by buoyancy. The warm air carries the energy to higher altitudes.





- In environmental studies, mainly in meteorology sometimes the convection includes horizontal air movements as well. In pollutant transport we focus on convection as the vertical form of air motion. Natural air parcel rise will happen if the air within a given air mass (parcel) is warmer than the surrounding air. The process is the same as a hot air balloon.

The buoyancy (F) can be expressed by air density difference of the surrounding and sample air masses

($\rho - \rho'$):

$$F = (\rho - \rho') g$$

where g is the gravitation



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg



Using the Newton's second law of acceleration (a) of rising

$$a = \frac{F}{\rho'} = \frac{\rho - \rho'}{\rho'} g$$

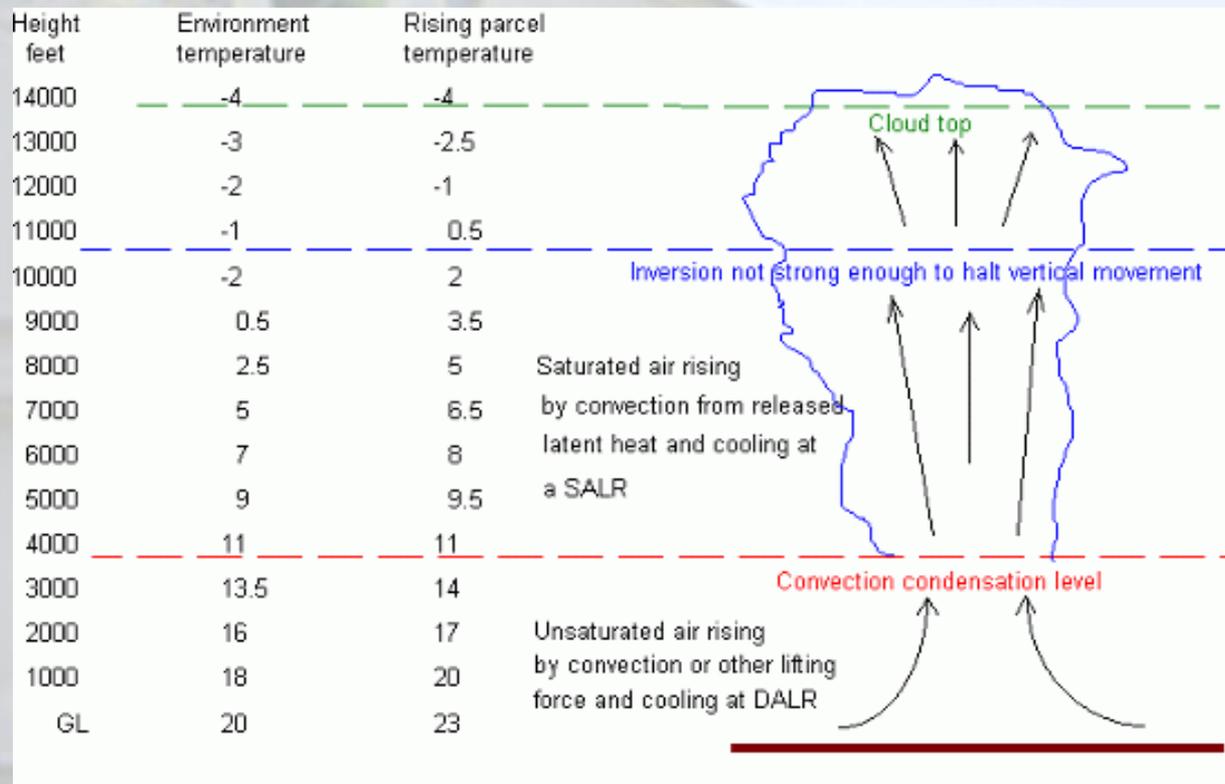
In this circumstances the acceleration of the warm air will be (if assume the $p \sim p'$ and using the ideal gas law):

$$a = g \frac{T' - T}{T}$$

where T' and T are the temperatures of air parcel and the surrounding air, respectively.



Fig. 30 Two temperature changes with consequences

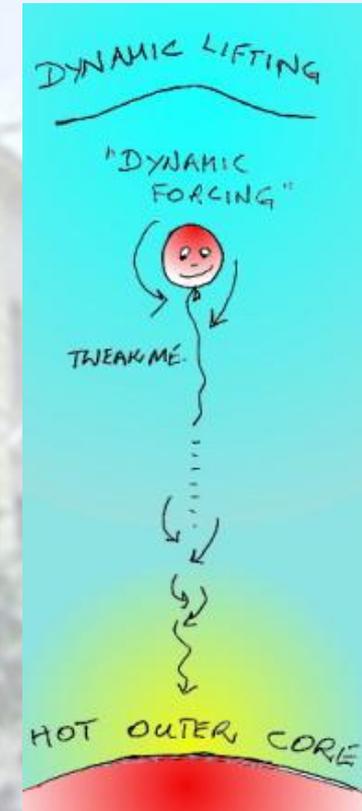


<http://www.auf.asn.au/metimages/instabilitycloud.gif>

Fig. 31 Rising balloon

The last equation communicates that the air mass rising only depends on temperature difference between the air parcel and the surrounding air. See later the stability of air!

The air can lift only those things what's weight is lighter than that of the weight of the air itself.



<http://users.indigo.net.au/don/nonsense/balloon1.jpg>

Two types of convection

Natural convection or **free convection** is if heat is transferred due to buoyancy coming from density variability caused by warming itself. It has importance in environmental pollution due to instability induced property mixing.

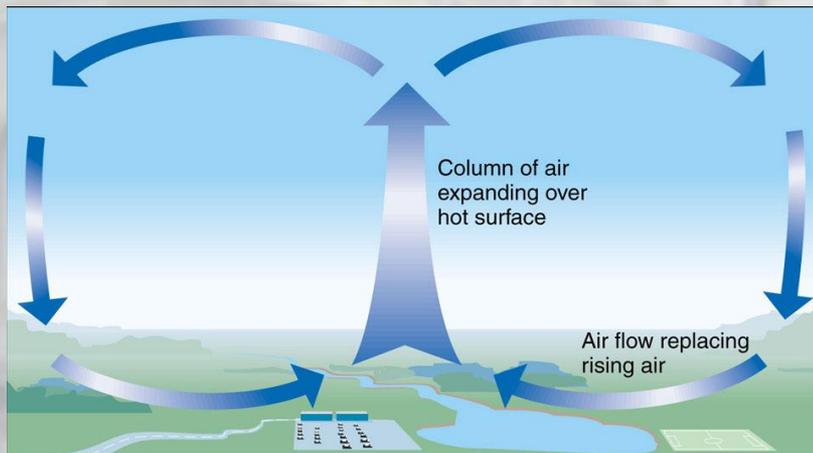


Fig. 32 The free convection

http://www.geog.ucsb.edu/~joel/g110_w08/lecture_notes/heating/agburt03_11a.jpg

In the **forced convection** the heat exchange is due to external sources (mountains, high buildings etc.) and not to natural temperature (air density) change. The ratio of advection and diffusion (movement from high to low concentrations) of heat is enough to characterize the forced convection.

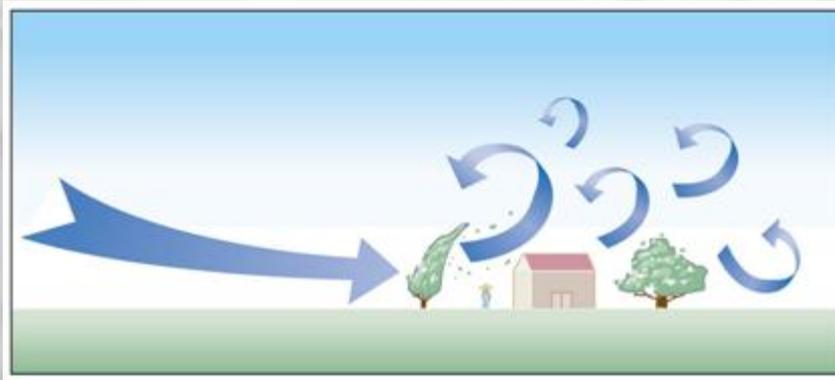


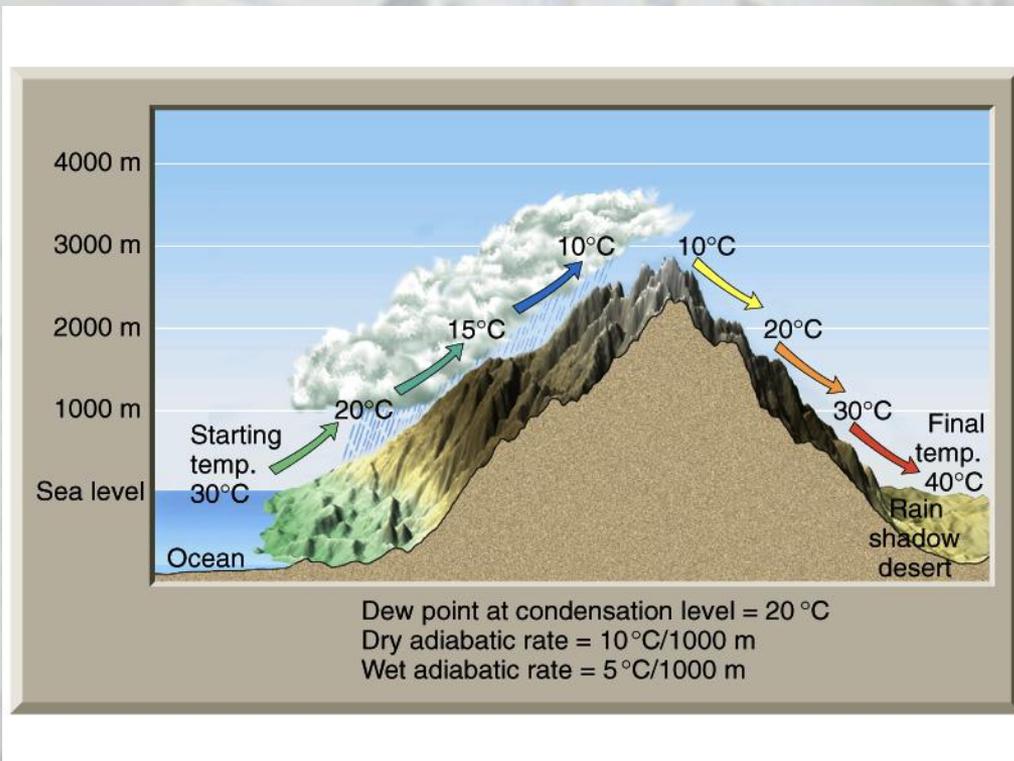
Fig. 33 The forced convection due to a building

www.geog.ucsb.edu/.../heating/heating.htm



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg

Fig. 34 A possible situation for temperature changes



The orographic lifting, where elevated terrain acts as a barrier to the flow of air. The lapse rates see also later



Importance of convective transport of air pollutants

- a) Convection lifts pollutants away from the surface
- b) In the rising convective column, precipitation may form and wash out the soluble pollutants
- c) Convection transports some pollutants into upper air levels to disperse the pollutants over great distances





The turbulent diffusion

Until now, the titled process handling is really problematic, it is not completely solved. Even though the process is extremely important for property mixing and in transport of systems, especially in those subjects dealing with contaminant transportation and combustion. In these processes, the turbulent diffusion acts as a quickly contaminant concentration reducing factor.

Do not mix the turbulent diffusion to molecular diffusion.





The air molecules are of small sized. Their Brownian motion is very intense. If there is a concentration gradient in the system as of the air, a mixing action is taking place. This mixing is important in pollutant diversion. The transport of masses is associated with random and chaotic air motions (in time). Turbulence is difficult to define; nevertheless, there are important features that all turbulent flows have got. These are as follows:

- unpredictability
- rapid diffusivity
- high levels of fluctuating vorticity
- dissipation of kinetic energy





Lesson 11

Study the turbulent diffusion. The turbulent coefficient. Impact of air temperature on air pollution – the air stability I.



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg



Possibility in study of turbulent diffusion

To study the turbulent diffusion the transport models of Eulerian and Lagrangian (discussed later) ones are widely applied. These models help us in understanding the turbulent process itself as a physical one. The models contain the chemical reactions and motion of the contaminants. Both vertical and horizontal wind, and additionally integrated Fickian diffusion theory are to account for proper assumption of turbulent diffusion.



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg



In the air, the diffusion is the result of concentration gradient from place to place

Turbulent diffusion is the *irregular* air movement, in which the wind constantly varies in both speed and direction. The intensity may be expressed in terms of flux, ψ ,

$$\psi = -K_z \frac{\partial c}{\partial z}$$

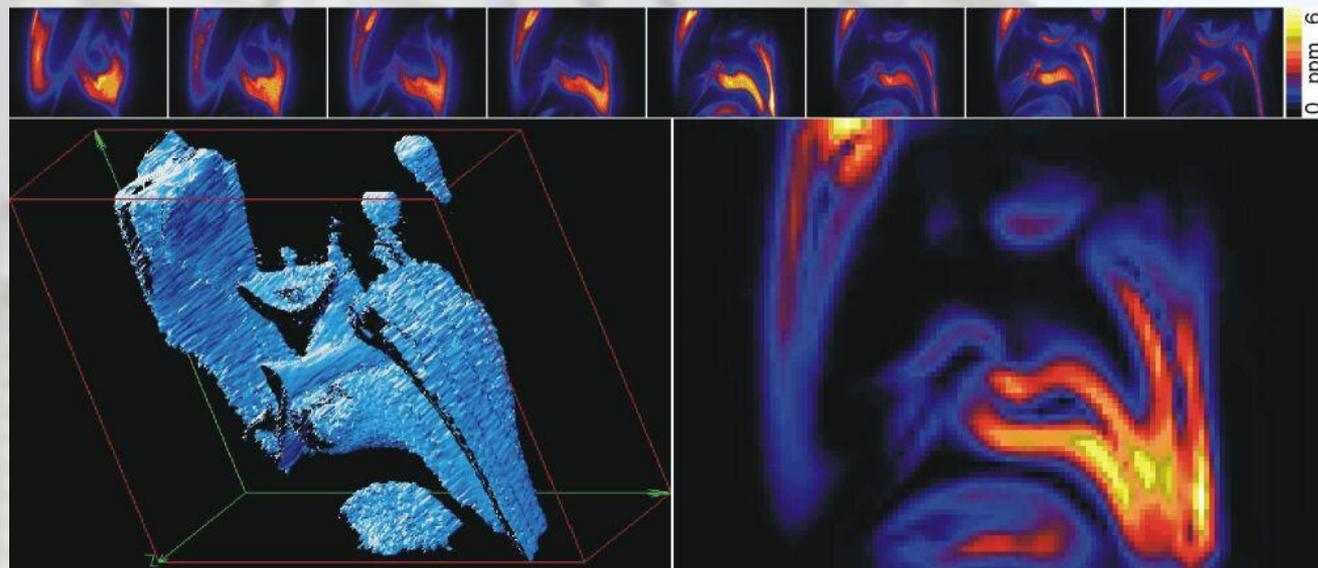
where K_z : diffusion coefficient

c : gas (pollutant) concentration



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg

Fig. 35 The turbulent diffusion in a flame (dilution as concentration change was expressed in ppm)



<http://laser.cheng.cam.ac.uk/wiki/images/b/b3/3DLIIMyag.jpg>



Turbulent coefficient

The turbulent diffusion is generally described by the turbulent diffusion coefficient (K_z). This coefficient is defined in a phenomenological sense, by analogy with the molecular diffusivities. It is important, that it does not have a true physical meaning. It depends on the flow conditions, and not on a property.

In most cases its average value is used in calculations, that is equal to $10 \text{ m}^2\text{s}^{-1}$. This seems to be quite a good assumption. In more precise work its values need to be suited to pollutant quality.



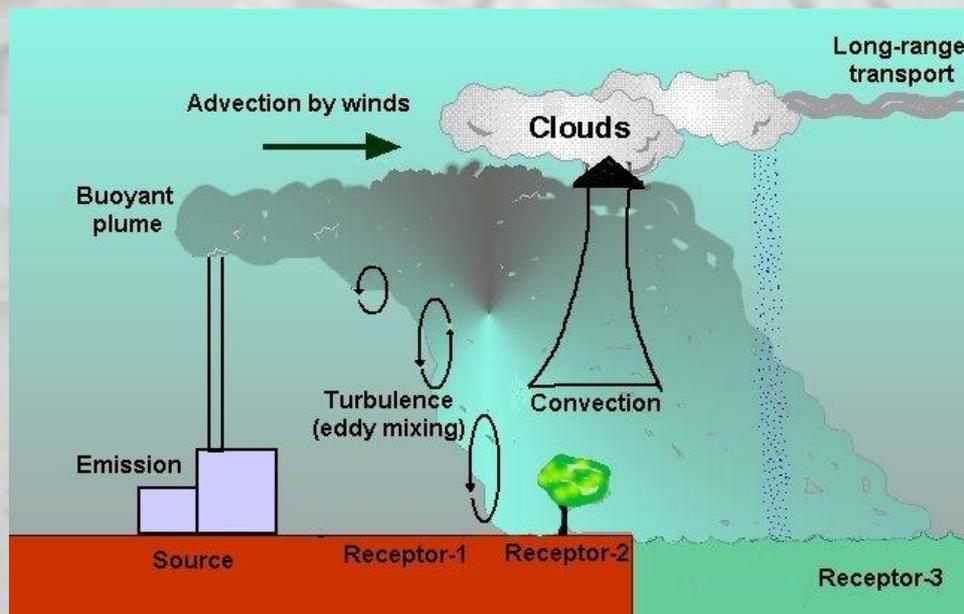


Importance of turbulent diffusion

- a) It mixes the atmosphere at the given elevation
- b) Causes - air pollutants
 - and any other substances
(for example water vapor, gases etc.)
 - as well as the energyto become **distributed at all elevations.**



Fig. 36 Relationship between the elements of air motion



All of the three processes (advection, convection, turbulent diffusion) are necessary to accomplished pollutant amalgamation (blending)

irina.eas.gatech.edu/lectures/Lec17.html



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg



2. Impact of air temperature on pollution: Stability of the air

In the air **adiabatic processes** are dominant, where there is no loss or addition of heat with the environment. Adiabatic temperature change occurs in a vertically displaced air parcel as a result of air pressure and volume variation (gas law!). Upward displacement causes air expansion with cooling, and downward displacement results compression and warming. In the troposphere, the vertical air temperature change relates to vertical air displacement .



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg



- In case of dry air the cooling with height is close to 1 degrees centigrade per 100m; this value is known as the **dry adiabatic lapse rate [DAR]**.
- If the ascending air contains moisture it expands and cools (adiabatic process), and on a given height it reaches the saturation point. Due to further cooling the water vapor condenses and the sensible latent heat liberates. The condensation process produces some extra heat enriching the rising air parcel's temperature. Finally, the cooling in moist air won't be as intense as in dry air. Just the opposite process can be found during evaporation process.



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg



Adiabatic lapse rates

This second adiabatic lapse rate for saturated air, is the **saturated adiabatic lapse rate [SAR]**. The value of SAR depends on such air properties as

- moisture content of the air
- air temperature and air pressure.

The average SALR is about 0.5°C for 100m.

The **environment lapse rate [ELR]** is the actual temperature change measured for a given time and place in the troposphere. It's average for the whole Earth atmosphere is $0.65^{\circ}\text{C}/100\text{m}$. The spatial and temporal variability of ELR is very high.



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg



Atmospheric stability

The atmospheric stability means a kind of resistance to any modifying influence in the air. In **stable air** cooling with height occurs and the heavy cold air parcel resists any vertical movement. This air parcel after being lifted, becomes cooler than that of the surrounding air, tends to turn back to the direction of ground. This is the stable air condition.

The stable air resists the lifting of the pollutant from the emission sources. Even though the contamination of higher altitudes may return back to the place of emission.





Lesson 12

Impact of air temperature in air pollution – the air stability II. Pressure systems and air pollution



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg



Unstable air

If the temperature of an air parcel declines on a less extent than the temperature of the surrounding larger air mass, the unstable air will be created. Here the lifted air becomes warmer and denser than the surrounding environment. The parcel rise is more intense than at stable air conditions. This is the **unstable air**. Later on this air is lifting until it cools and reaches the dew point. Instability always causes upward or downward motion. Upward motion may produce precipitation. Downward motion as a result of descending air adiabatically warms, will be unsaturated , and follows its way on DAR.



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg



The instability is a favor state of the air regarding the pollution dispersion. The lifting of the air transports all the contaminants from the sources. It dilutes the pollutant concentrations. The precipitation washes out the air, cleaning its detrimental constituents further.

There is a third variation concerning the average lapse rate and its momentary value. It is a very rare situation when the above two lapse rates are equal. This is the case of **neutral equilibrium**.



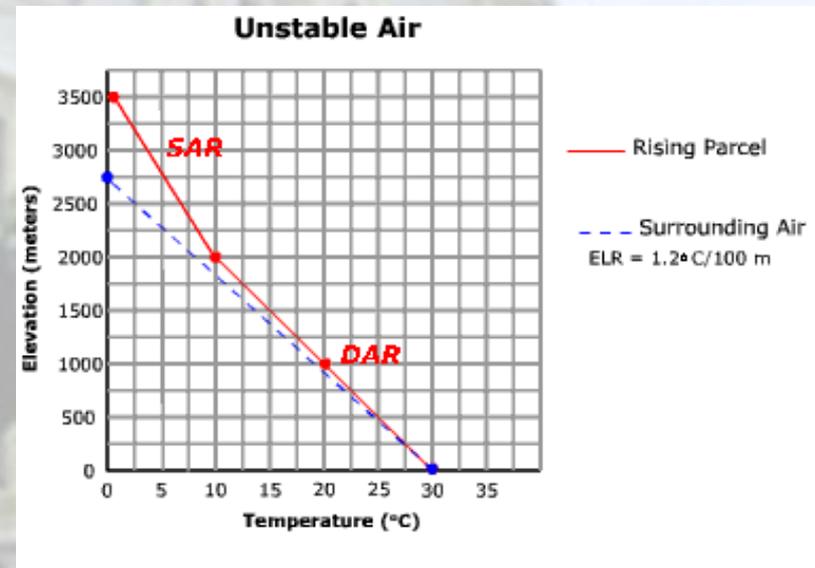
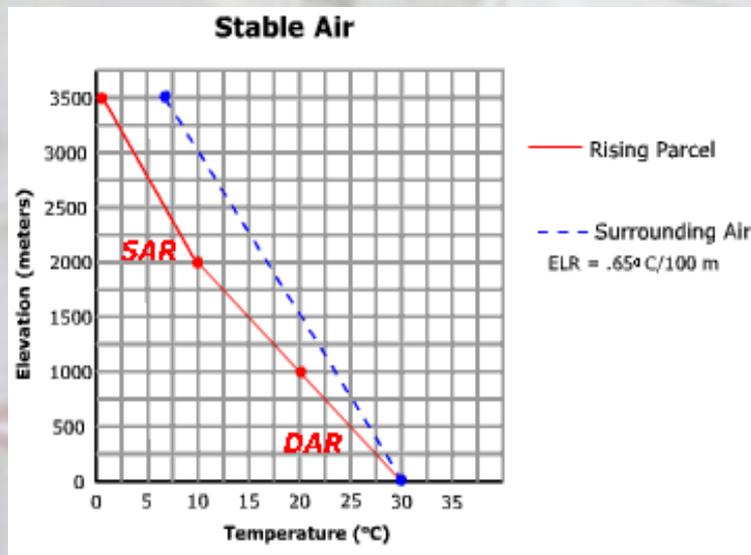
Fig. 37 Vertical temperature variations

1. $T_{\text{parcel}} > T_{\text{mean}}$

Blue: average lapse rate,

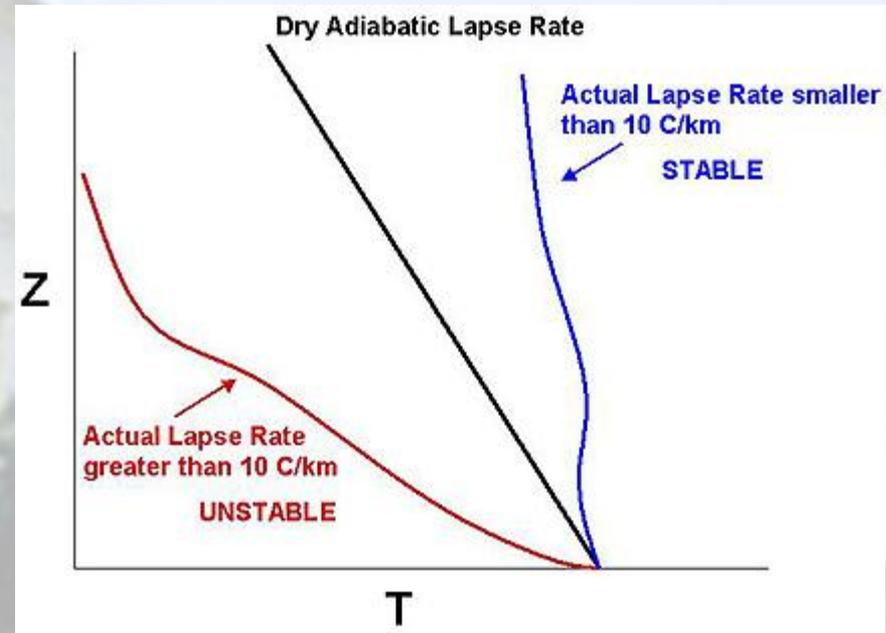
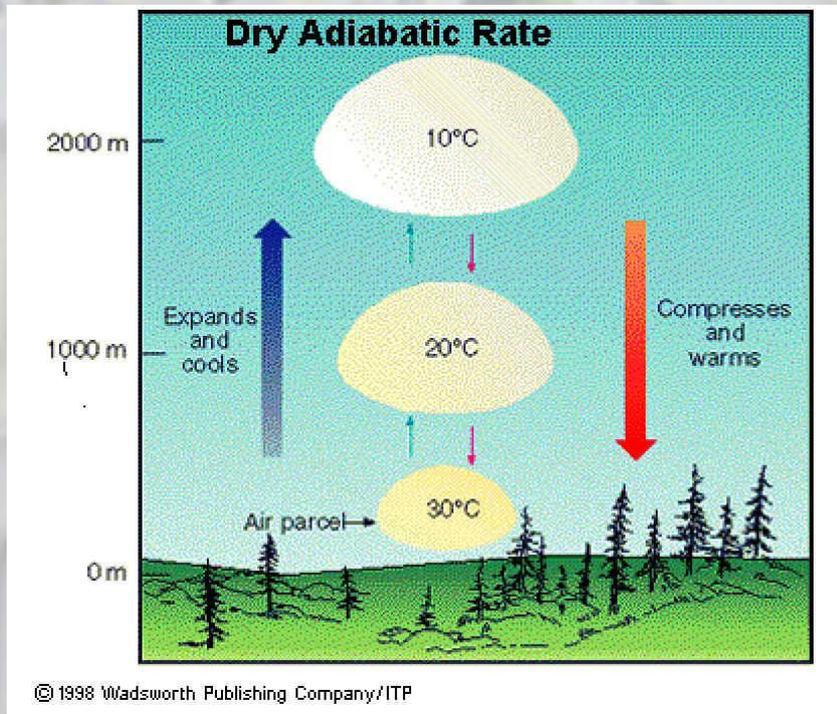
2. $T_{\text{parcel}} < T_{\text{mean}}$

red: lapse rate of the air parcel



3. $T_{\text{parcel}} = T_{\text{mean}}$

Fig. 38 The lapse rates and air stability



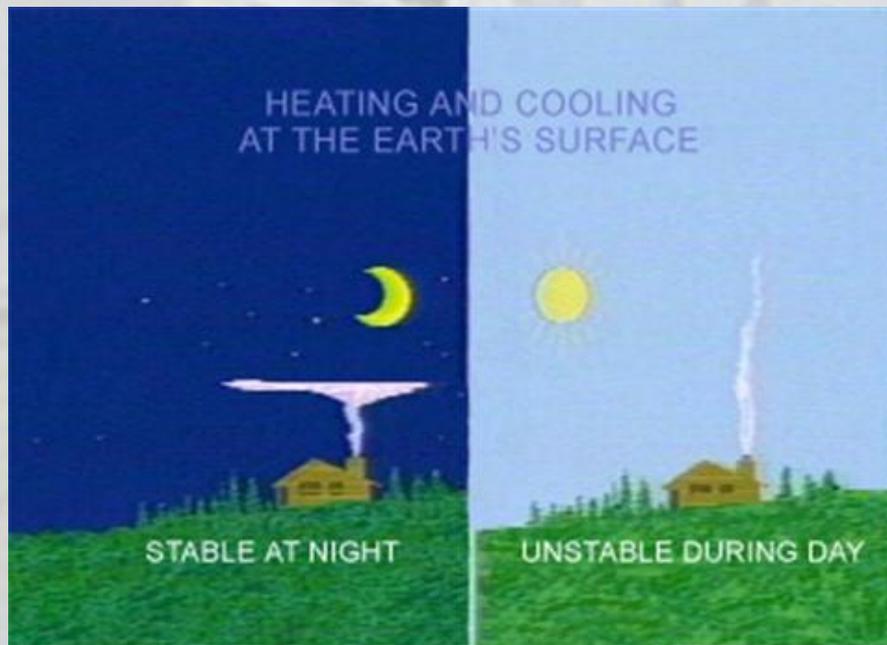
<http://www.fas.org/irp/imint/docs/rs/t/Sect14/stability8.jpg>

<http://kkd.ou.edu/METR%202603/dry%20ad%20lapse%20rate.jpg>



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg

Fig. 39. The appearance of different atmospheric states



Yearly variation can also be discussed. In winter stable, and in summer unstable state used to be.

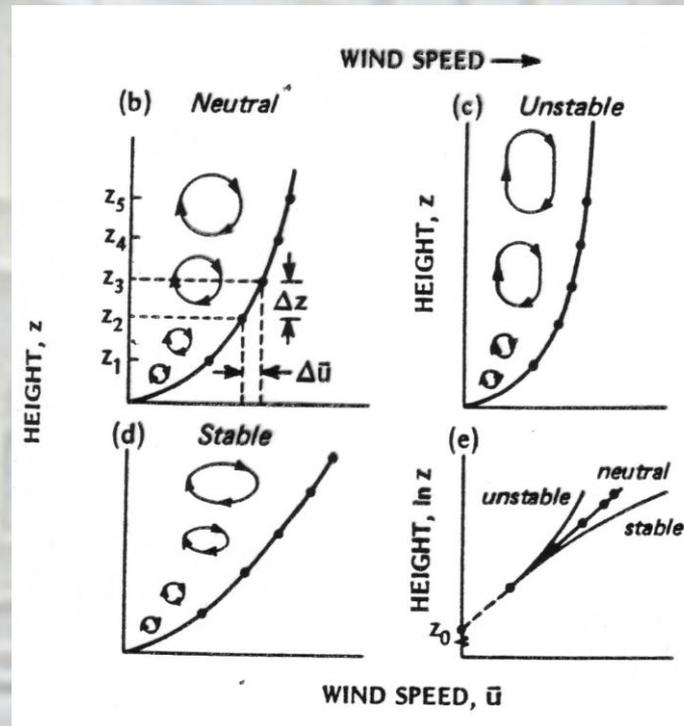


Summing the atmospheric stability we get three variations

- If the air is cooler (more dense) than the surrounding air, then it is called ***stable air***.
Stable air resists vertical movement
- If the air is warmer (less dense) than the surrounding air, then it is called ***unstable air***.
Unstable air will rise (much like a hot-air balloon)
- Neutral **equilibrium** – the two air temperature decline rates are the same



Fig. 40 Atmospheric stability determines the eddy formations as well (Oke 1987)





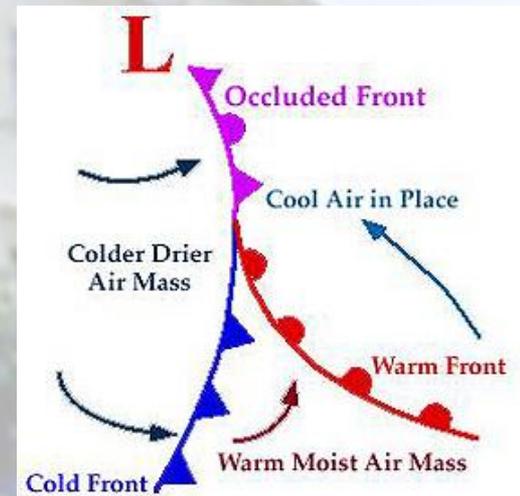
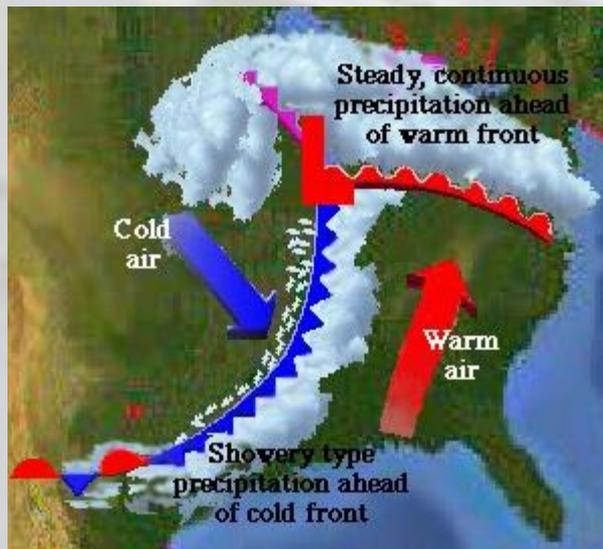
3. Pressure systems and pollution

The cyclones have the smallest air pressure inside the formation system. The depressions (lows) are associated with converging wind motion, and the air is lifting up leading to convergence below. The effect of cyclone is positive in pollution decline. There are two fronts inside a cyclone. At first the warm front arrives with slow air motion, that forms stratus clouds and holds light precipitation. This is followed by the cold front with cumulus clouds, producing heavy storms and precipitation, that washes out the contaminant air. After the cold front the atmosphere will be clean, as it sweeps all the contaminants.



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg

Fig. 41 The two fronts with their precipitation events



<http://z.about.com/d/weather/1/0/P/-/-/-/occludedfront.jpg>

earthscience.wordpress.com/.../day-158-fronts/



The influence of anticyclone

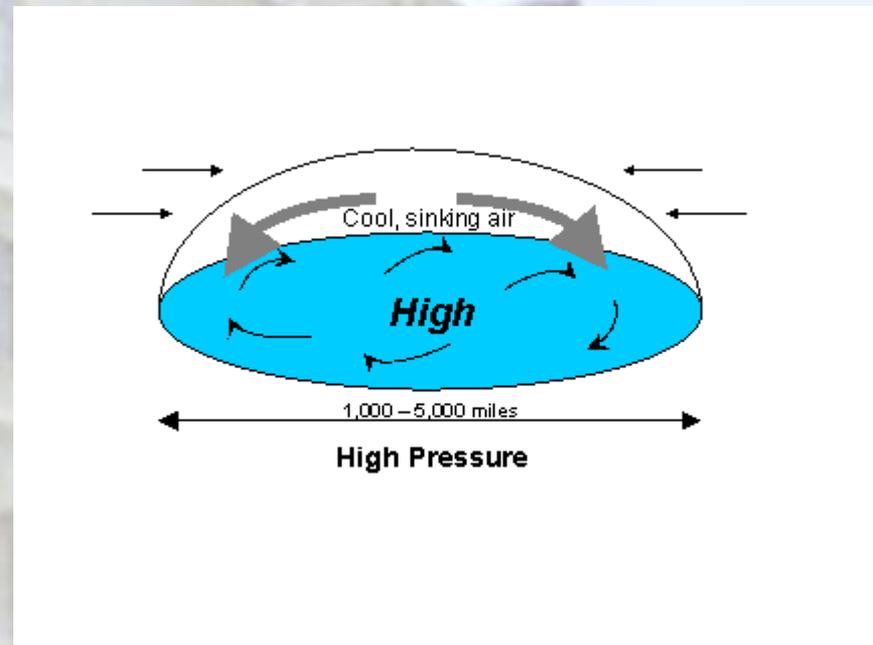
In the presence of pollution sources, problems may arise from the interaction of weather-pollution conditions. The air pollution problems may deepen especially when high air pressure (anticyclone) dominates. Subsiding motions within an anticyclone suppress air back to the direction of ground. In some cases the forming of *inversion* makes the circumstances even more problematic. The inversion closes the way to leave the pollutant from the surface to higher levels. A *temperature inversion* traps the pollutant and can be removed only by strong wind. Pollution problems improve when cyclone occupies the place of the anticyclone.



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg

Fig. 42 An anticyclone flow chart

The higher pressure near the surface flows outward toward lower pressure. The Coriolis force also influences the wind direction.



http://www.weatherquestions.com/High_pressure.gif



Debrecen Egyetem
Mezőgazdaság- Élelmiszertudományi és
Környezetgazdálkodási Kar



Pannon Egyetem
Georgikon Kar



Thank you for attention!



A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg