INZRAK

Enhanced environmental protection inspection for efficient control of air quality monitoring and of all entities under obligation within system of greenhouse gas emission allowance trading, in order to achieve better quality of air in Republic of Croatia

REPUBLIKA HRVATSKA
MINISTARSTVO ZAŠTITE OKOLIŠA I ENERGETIKE

EKONERG

safu SREDIŠNJA AGENCIJA ZA FINANCIRANJE I UGOVARANJE

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THEME 1: Pollution of the atmosphere

1.4 METEOROLOGICAL FACTORS

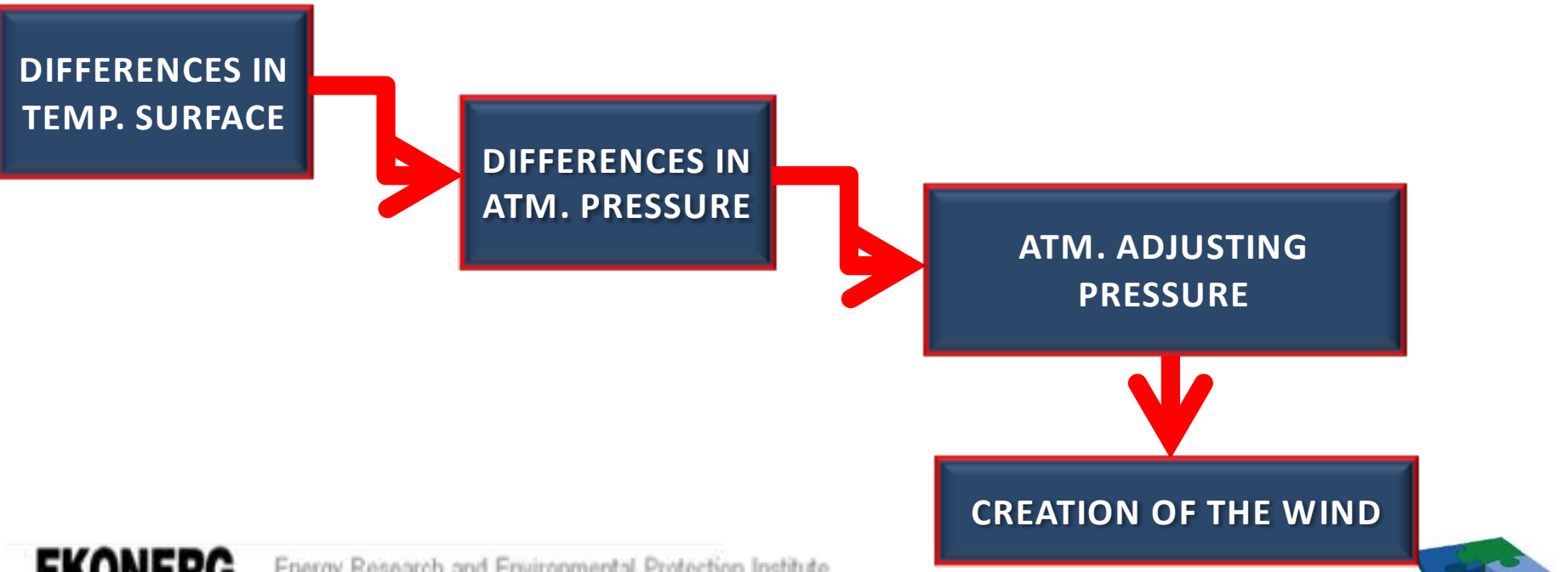
Factors that affect the distribution of pollutants in the air as well as on the transport over long distances are:

- **ATMOSPHERIC STABILITY**
  - The horizontal circulation (wind-speed and direction)
  - Vertical circulation (turbulence)
- **AIR MASSES**
- **THE ATMOSPHERIC FRONTS**
- **PRECIPITATION**
- **AIR TEMPERATURE**

1.4 METEOROLOGICAL FACTORS

The differences in the warming of the Earth's surface

The differences in the warming of the Earth's surface are the basis for the creation of the wind according to the following



1.4 METEOROLOGICAL FACTORS

The differences in the warming of the Earth's surface

The energy received from the Sun absorbs the Earth's surface to varying degrees.

Example:

The land is absorbed and stored energy different from the water. Dry surface heated and cooled faster than the water surface, while the water surface will heat and cool more slowly than the land for several reasons:

- constant movement of water distributed the heat
- The Sun's rays penetrate through the surface of the water and thus warm the water to a certain depth

1.4 METEOROLOGICAL FACTORS

- due to the different thermal capacity, requires a greater amount of energy to heat water in relation to the same mass of soil

- water evaporation process cools the water surface.

The different types of land surfaces have different ability of absorption and storage energy.
Color, shape, texture of the surface, vegetation and vicinity to buildings affect the warming and cooling the soil.

1.4 METEOROLOGICAL FACTORS

- The sandy coast, roads and buildings are quickly become warm during the day, resulting in a higher temperature of the air above them

- The area under the vegetation (forests and meadows) heat up more slowly, and the air temperature over them is lower

During the night, the situation is reversed.

1.4 METEOROLOGICAL FACTORS

Heat transfer

Heat energy in the atmosphere, except the radiation spreads in processes:

CONDUCTION
CONVECTION
ADVEKCTION

Conduction is the spontaneous transfer of heat energy through matter from areas of higher temperatures in the area of the lower temperatures, and therefore it acts for the purpose of compensating for temperature difference.

1.4 METEOROLOGICAL FACTORS

Example of conduction:

Heated ground heats the air conduction.

Convection is the directed motion, i.e. fluid flow (liquid and gas), where the hotter fluid moves according to the colder and transfers the warmth of the area.

Example of convection:

Heated air, since it is lighter than the surrounding cold air, raises up and transfers the heat vertically by convection.

1.4 METEOROLOGICAL FACTORS

Advection is the horizontal heat transfer between the individual parts of the Earth.

Example: Advection

Heat transfer in horizontal air currents

1.4 METEOROLOGICAL FACTORS

Atmospheric circulation

Motion of air masses occurs due to efforts to make equal air pressure in different areas. Imbalance in air pressure occurs as a result of the different insolation and different heating of the Earth's surface.

Atmospheric circulation is extremely important factor to the distribution of pollutants in the air.

1.4 METEOROLOGICAL FACTORS

Atmospheric circulation (wind)

Air flow is one of the basic characteristics of the atmosphere, and the wind as the horizontal component of the flows of atmospheric air in relation to the Earth's surface is an essential element in the general circulation of the atmosphere.

Wind is the vector and determines its direction and speed, and marks that side of the world from where the wind is blowing:

The North wind always blow from the North in the direction of the South!

1.4 METEOROLOGICAL FACTORS

The wind also affects the force of the pressure gradient, which occurs due to the differences in pressures. The air moves from area of higher in the area of lower air pressure.

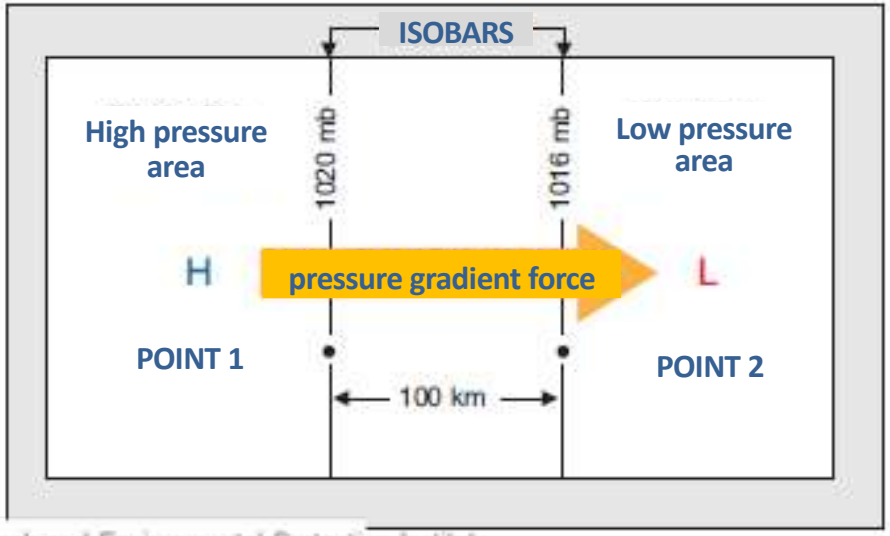
Pressure gradient is described by the following equation:

pressure gradient = pressure difference/distance

1.4 METEOROLOGICAL FACTORS

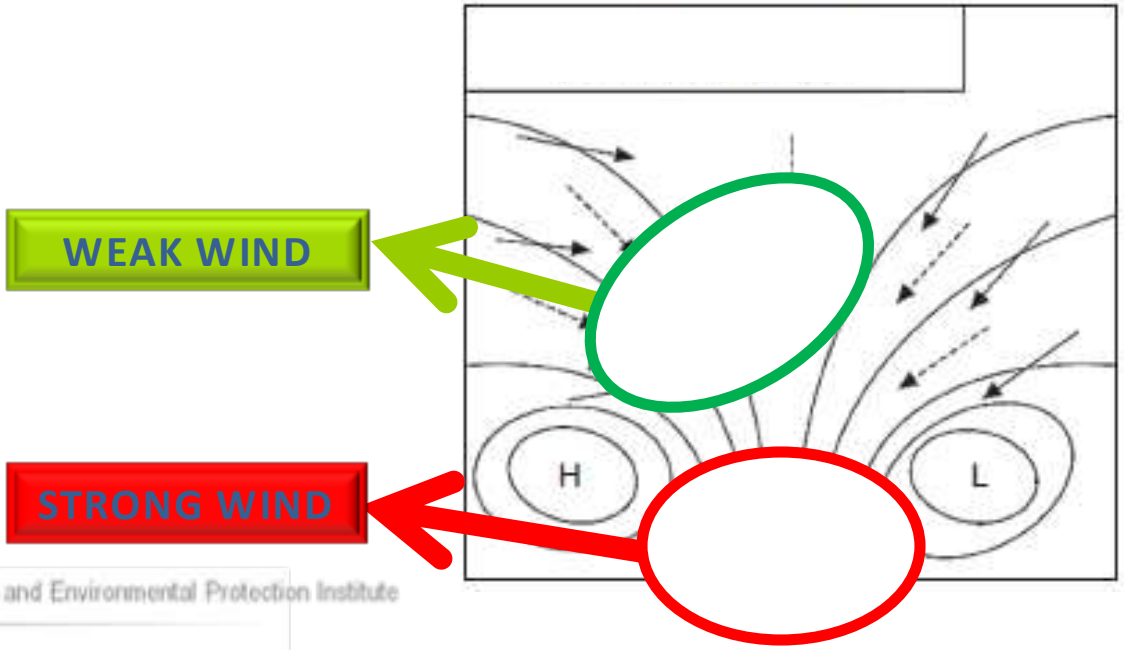
Example:

The schematic diagram shows the pressure gradient force between Point 1 in the High Pressure Range (1020 mb) and Point 2 in the Low Pressure Range (1016 mb). The distance between the points is 100 km and the pressure gradient is 4 mb at 100 km.



1.4 METEOROLOGICAL FACTORS

If the pressure on a small horizontal distance is large, and the isobars on weather maps "condensed", there will be big pressure gradient force and strong wind.
Conversely, if the isobars are spaced, the pressure gradient is small, and the wind is weak.



1.4 METEOROLOGICAL FACTORS

Systems of local winds

The physical characteristics of the Earth's surface under the common name of the topographical elements cause a thermal and mechanical air circulation.

Thermal circulation is a consequence of different heating surface which occurs because of the different types of surfaces absorb differently and variously released warmth in the air at the ground.

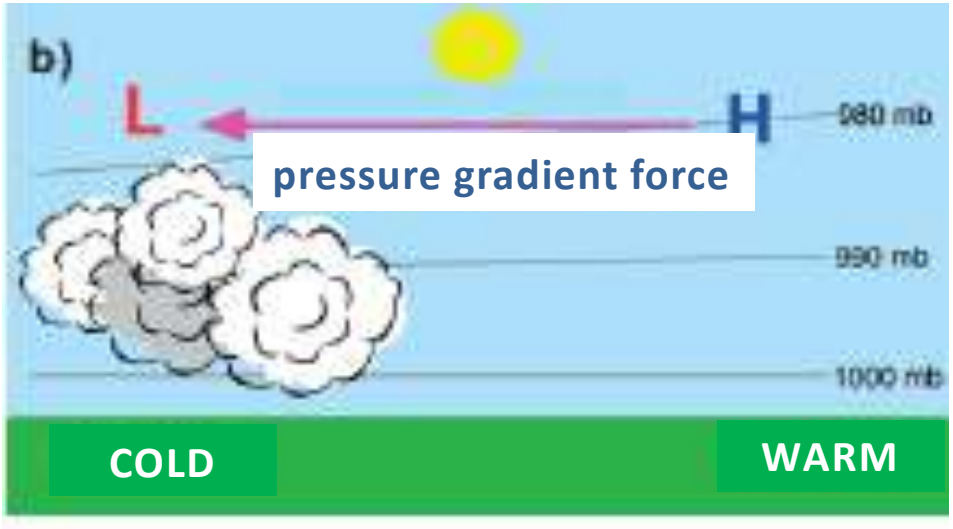
1.4 METEOROLOGICAL FACTORS

The generation of thermal circulation

This figure shows a situation in which there is no pressure or temperature gradient, so therefore there is no phenomena of the wind. Atmospheric pressure decreases with height (1000 to 980 mb).

1.4 METEOROLOGICAL FACTORS

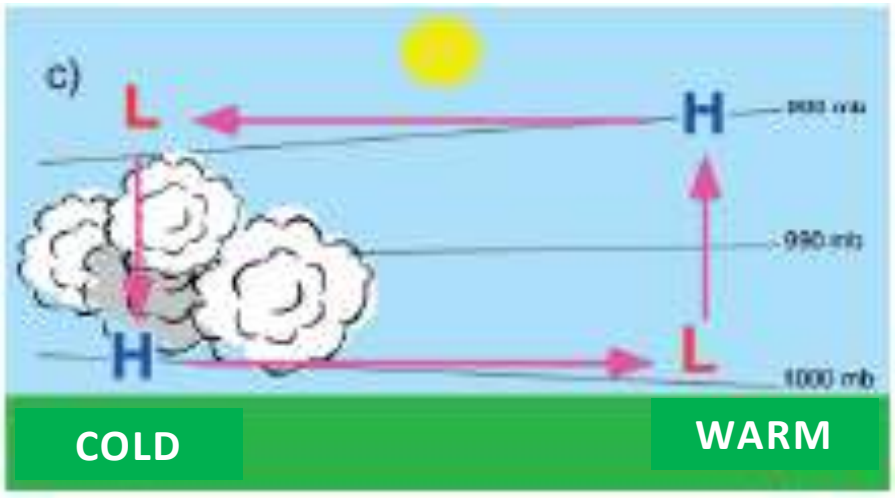
The generation of thermal circulation



On the right is visible the warming of the soil which transfers the heat to the air over the area. The warm air rises and isobar spacing increases. In the upper parts of the atmosphere pressure gradient occurs and the air begins to move to the left, according to the area of lower pressure.

1.4 METEOROLOGICAL FACTORS

The generation of thermal circulation



This picture shows complete air circulation. At a time when warm air arrives above the clouds, it cools and pounds. Now underneath the cloud creates higher air pressure that drives the air to the right due to the pressure gradient force. Such circulation is initiated by uneven warming of the Earth's surface.

1.4 METEOROLOGICAL FACTORS

The generation of thermal circulation

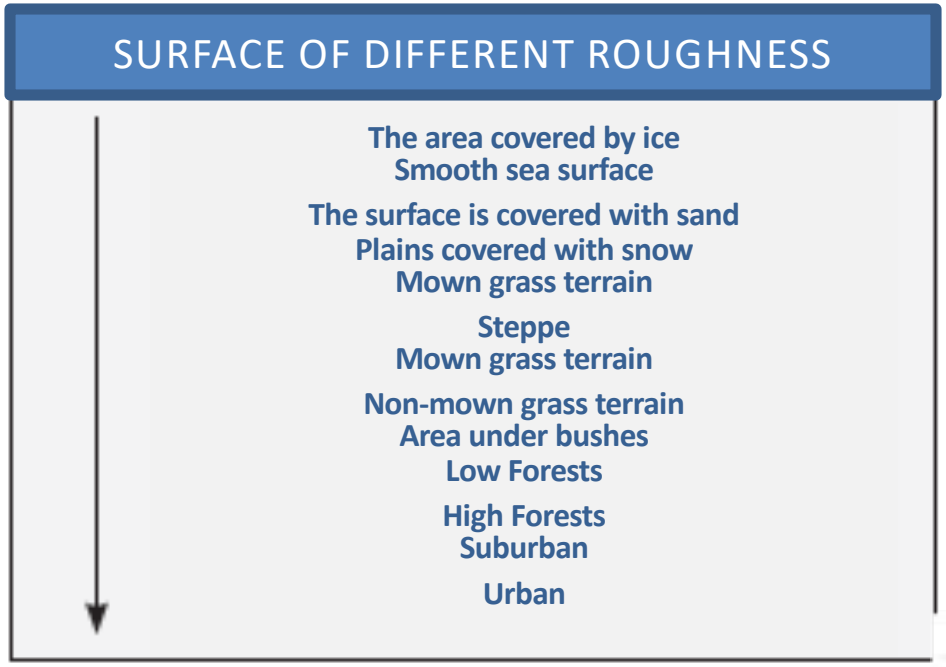
Mechanical circulation occurs due to winds blowing over of topographic elements of different shapes and heights. There are four topographic categories that have the most influence on the thermal and mechanical circulation:

- plain
- mountain/valley
- land/sea
- urban area

1.4 METEOROLOGICAL FACTORS

Plain

Plain is a typical terrain which mechanical air circulation depends on the amount of natural or human hand created prominence due to the influence of the friction.

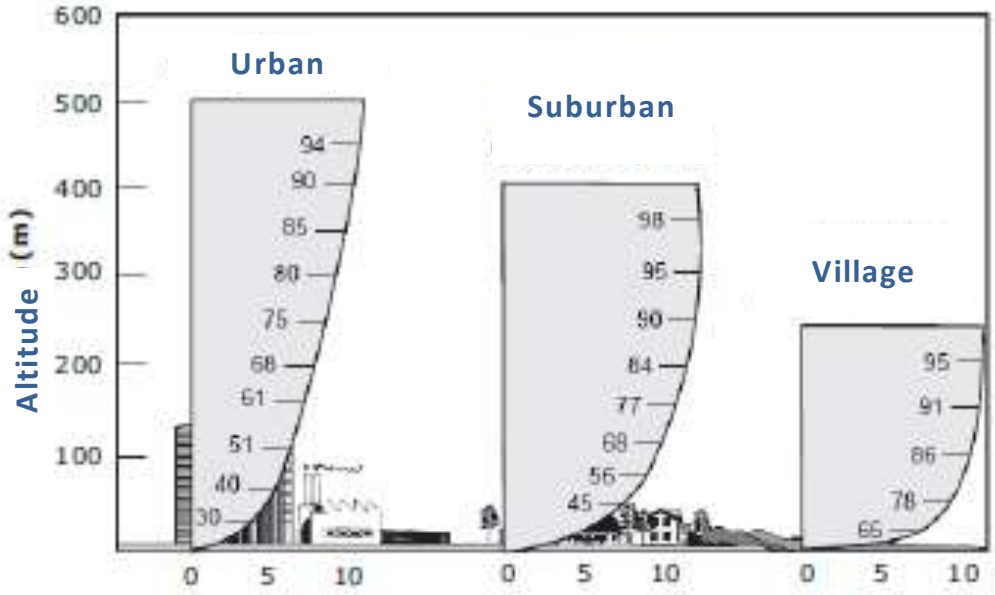


List of area of different degrees of roughness. At the top of the list are the smooth surface with the smallest impact on the friction, and toward the end of the list the roughness increases, and with it the friction.

1.4 METEOROLOGICAL FACTORS

Plain

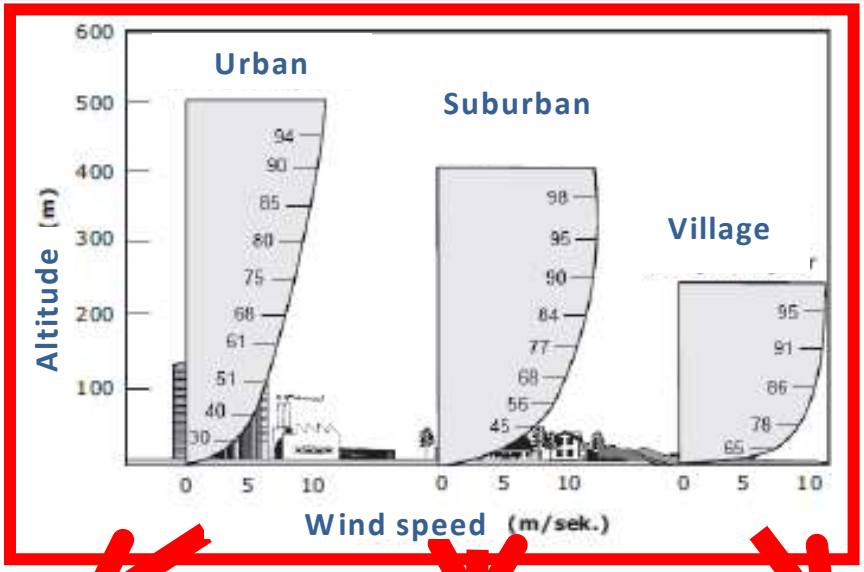
The height and density of the vertical barrier intensifies the impact of friction on the speed of the wind, which results in a change of the profile of the wind with height.



The picture shows an increase in wind speed with height for three basic types of terrain: a city with tall buildings, suburban area with low houses and the lowland village.

1.4 METEOROLOGICAL FACTORS

Plain



In the area of the city, due to friction, high buildings are slowing down the speed of the ground-level of the horizontal wind which then changes direction and comes to the TURBULENCE.

The turbulence was less pronounced in the suburban area, because the friction is less.

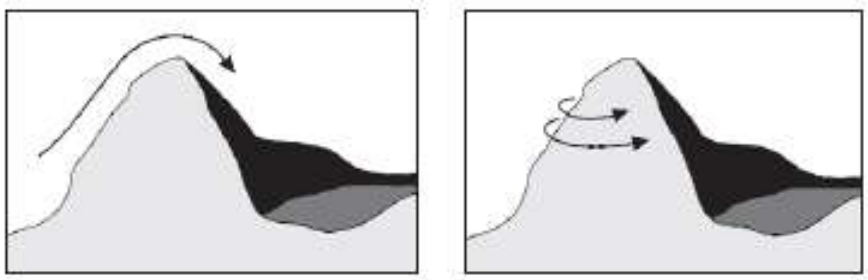
The turbulence was the least pronounced in the lowland village because of the least friction.

1.4 METEOROLOGICAL FACTORS

Mountain/Valley

Mechanical air circulation in the topographic category Mountain/Valley is closely linked with the size, shape and orientation of the topographic element and because of this is different for each individual instance.

Despite of diversity, there are two main directions of the wind blowing in such area. One is the endeavor of the air masses to rise over an obstacle, and the other occurs in cases of temperature inversions (the top layer of air is warmer than the bottom) when mass rounds mountain.



1.4 METEOROLOGICAL FACTORS

Mountain/Valley

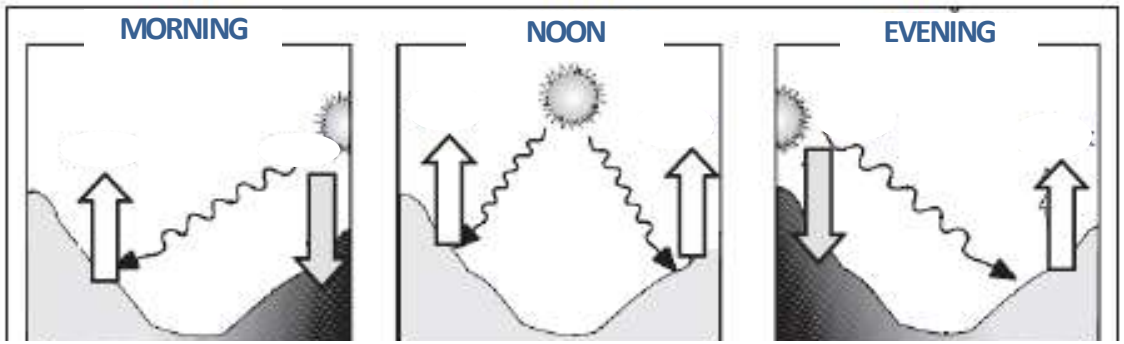
Thermal circulation is also associated with the size, shape and orientation of the topographic and distinct element is given the time of day.

Heating will also be affected by vegetation, and the slopes that are harvested will be less heated from rocky slopes.

1.4 METEOROLOGICAL FACTORS

Mountain/Valley

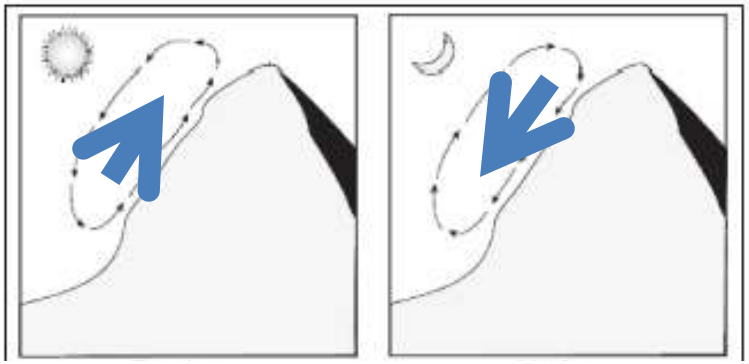
Because of the Sun's position on Earth's surface in the morning hours warms one side of the mountain, and the heated air above this slope rises as the cold air over the other unheated slope pounds. At noon, when the Sun is in a zenith, both sides of the slopes are heated as well as the air above them that is raised on both sides. In the evening the situation is reversed from the morning.



1.4 METEOROLOGICAL FACTORS

Mountain/Valley

Due to the heating of the surface of the slope of the mountain during the day and cool at night, the wind is changing within a 24-hour period. During the heated air rises and air circulation is directed towards the top of the mountain, and at night the circulation reversed due to the cooling of air at night which plunges.



1.4 METEOROLOGICAL FACTORS

Land/sea

Thermal characteristics of the land and sea are different.

- **The land and the buildings on it are heated and cooled relatively quickly**
- **The sea is heated and cooled relatively slowly**

Because of that, the water temperature does not vary substantially in a shorter period of time, but rather follows seasonal changes. This is because the solar radiation penetrates into the land only a few inches in depth, while in the water column penetrates much deeper.

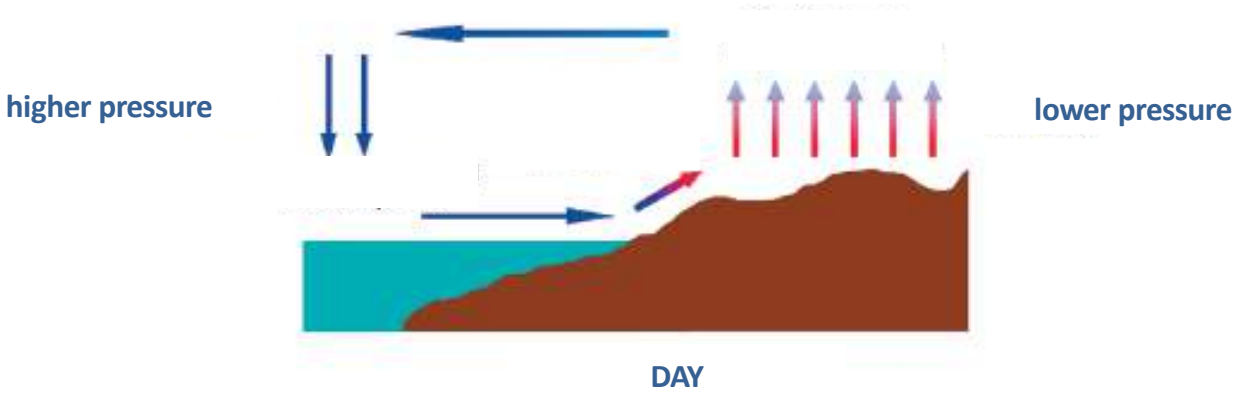
That is why the release of heat from the mainland is larger, and with the surface of the water less. On the inferior water heating influence:

- **evaporation**
- **mixing of surface and deep layers of water**

1.4 METEOROLOGICAL FACTORS

Land/sea

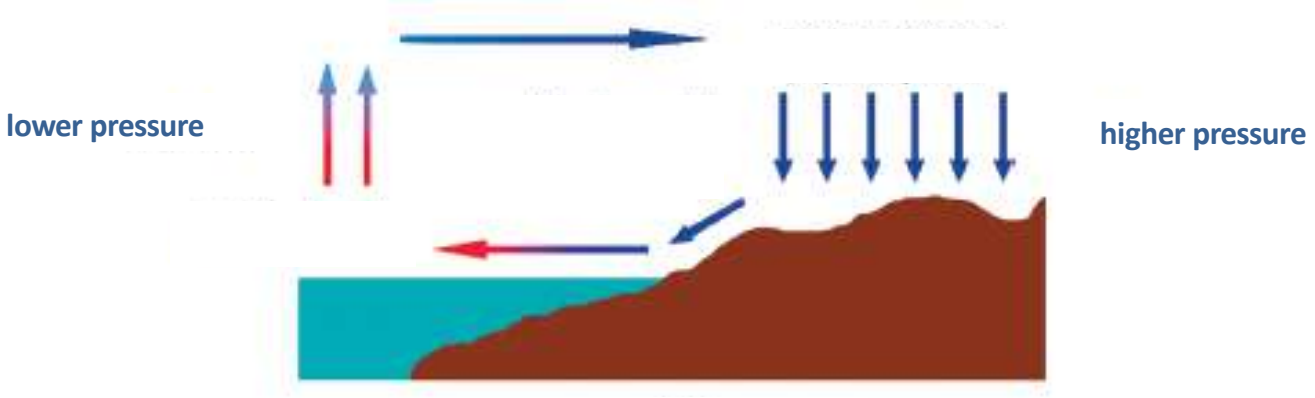
Warmer air over land during the day is easier and is raised and at the altitude of approximately 400 m rotates towards the sea. Moving towards the sea, the warm air is cooled slowly and a bunch of above the sea, so as a heavier (the density of air is increased) begins to descend towards the sea. That the circulation was closed, it begins to blow the wind from the sea (sea breeze).



1.4 METEOROLOGICAL FACTORS

Land/sea

At night, the situation is reversed. The land cools more quickly than the sea, so at night the temperature of the air above the sea is greater. Warmer air above the sea rising, moving to the land, so at night the wind's blowing from the land (land breeze).The difference between the temperatures of land and sea at night is much smaller than the daily temperature differences. Therefore, the wind from the land at night is weaker than a sea breeze.



NIGHT

1.4 METEOROLOGICAL FACTORS

An urban area

The air over the urban area is warmer air from the natural environment and is such an area called heat island.
To this phenomenon occurs because the asphalt, concrete and urban structures absorb a greater amount of solar energy than the vegetation and soil. At night, the energy is slowly released which prevents the cooling air. In the urban centre wind is mainly weaker than in the surrounding area, and is also less evaporation.

1.4 METEOROLOGICAL FACTORS

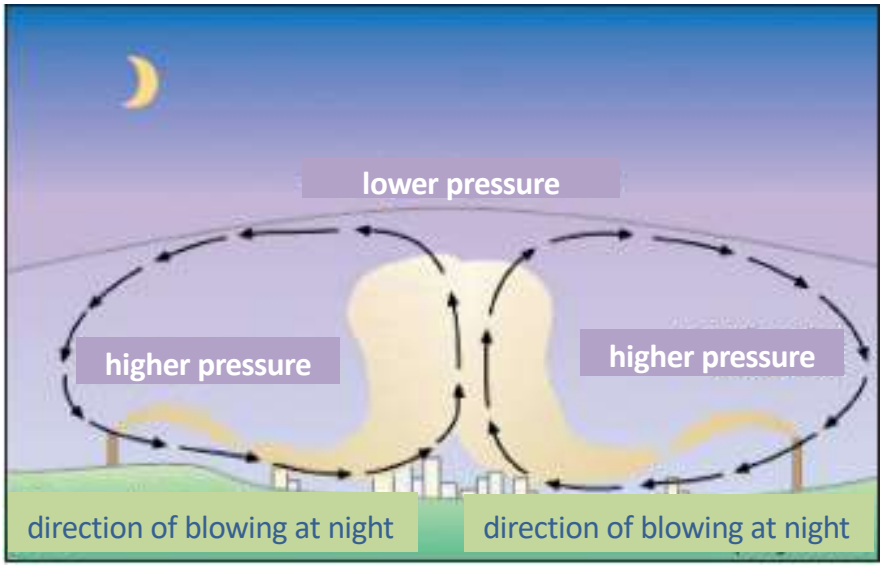
An urban area

Due to the heating of the air over cities, the atmosphere becomes unstable, which reinforces the high-altitude air currents that help in the formation of clouds and lightning.

In addition, due to the rise of hot air, especially at night, the area of the lower air pressure is created around the city as compared to the ambient air pressure outside the city so that light air flows from the environment toward the city.

1.4 METEOROLOGICAL FACTORS

An urban area



Such a situation favours the accumulation and retention of pollutants in the air over the city, and increases at the existence of a temperature inversion which prevents vertical mixing of layers of air.

1.4 METEOROLOGICAL FACTORS

Air masses

Air masses are macroscale phenomena because they cover a large area of several thousand square feet and reaching a height of several thousand metres.

These are the relatively homogeneous air volumes that get their basic characteristics (temperature and humidity) in the area of origin, provided that they remain sufficiently long over this area to assume its characteristics. Air masses favor the spread of pollutants over long distances by distributing them to large areas.

1.4 METEOROLOGICAL FACTORS

The atmospheric fronts

The atmospheric fronts are narrow border areas between atmospheric air masses of different properties.

If the air masses approach one another, the frontal zone narrows, the transition from one to the other air mass becomes sharper, the front becomes more pronounced, and this process is called frontogenesis.

If the air masses distancing, the frontal zone is widening, the differences in meteorological elements become less pronounced, the front gradually loses its importance and the process is called the frontolysis.

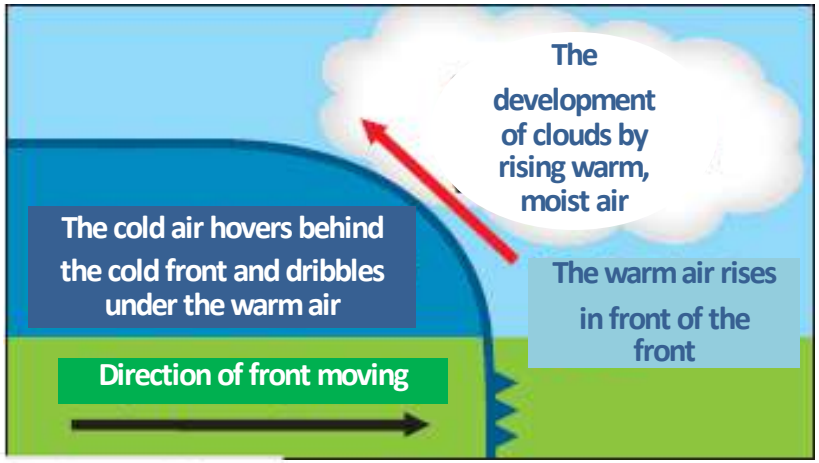
1.4 METEOROLOGICAL FACTORS

The atmospheric fronts

According to the temperature characteristics of front sort on:

cold
hot
stationary
ocluding

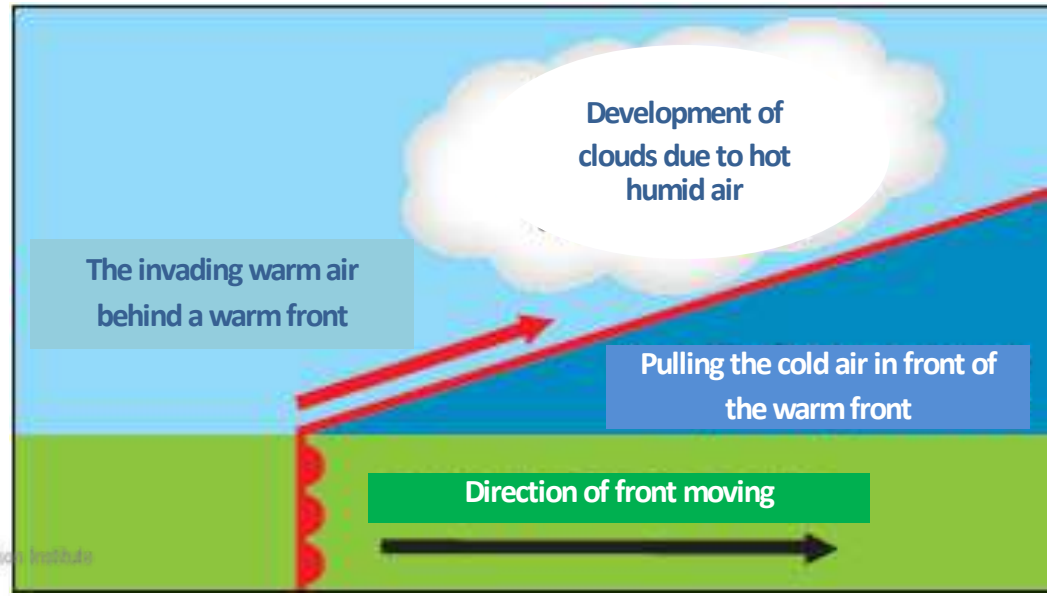
In the cold front the cold air reaches the warm area and comes to its "underlining" underneath the hot air. The reason is its higher specific weight. Due to the rise of the hot air in several layers, water vapor condensation and cloud formation occur.



1.4 METEOROLOGICAL FACTORS

The atmospheric fronts

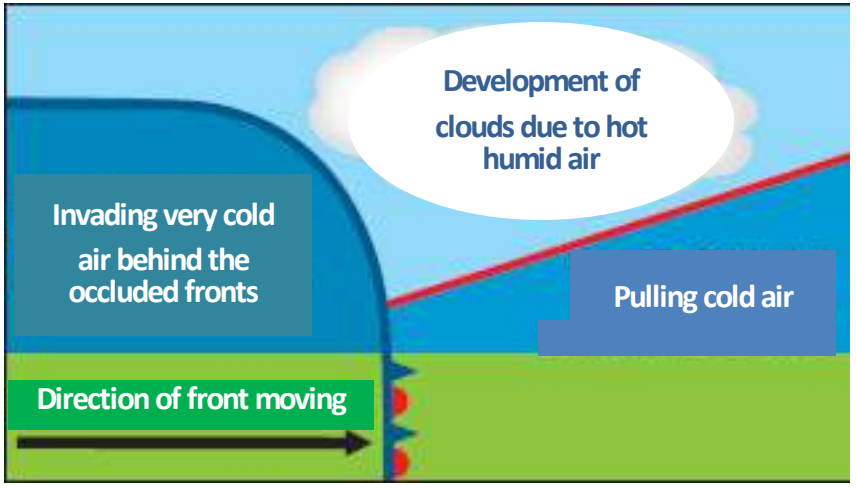
In the warm front the warm air begins to reach the cold air, and because of its specific lightness, it "climbs" over the cold. Therefore, the boundary of the hot and cold air masses is inclined towards the cold air. Because of the hot air rising over the colder, condensation of water vapor is produced, ie the formation of cloudiness along the frontal surface.



1.4 METEOROLOGICAL FACTORS

The atmospheric fronts

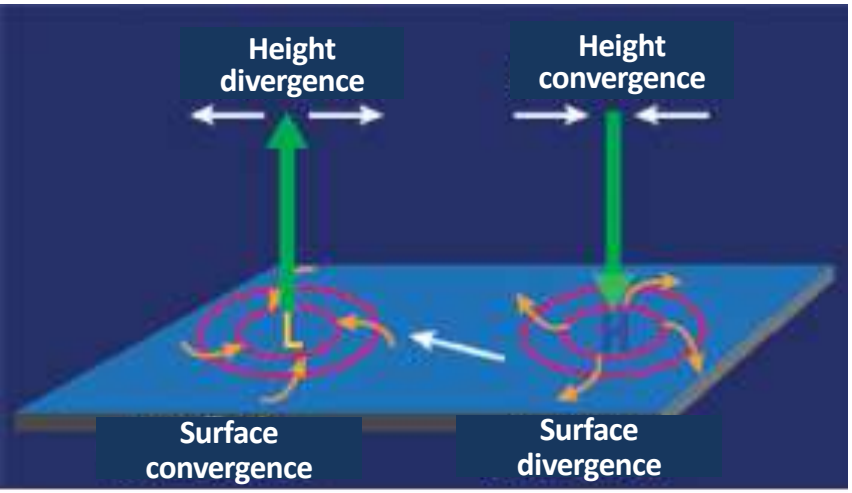
Occluded front is created because the cold front is faster than hot, so after some time, four to five days on average, it will reach the warm front. The cold air will reach the cold air mass that the warm air was pushing in front of it. As a result, the warm air will be suppressed in height. As a result, the warm air will be suppressed in height. Now we have three air masses: two cold in the ground floor and one warm above them. Such a situation is called occlusion.



1.4 METEOROLOGICAL FACTORS

Vertical air flow and atmospheric stability

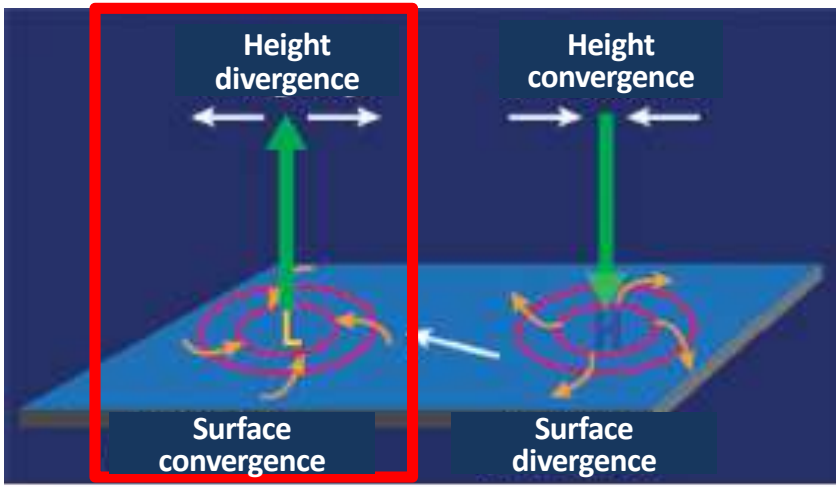
Vertical circulation of air is important for the spread of pollutants as well as the horizontal flow (wind). Both the air flow are connected to each other in the following way:



To equalize surface convergence, the air moving towards the center of the low pressure zone (cyclone) rises slowly and at a height of about 6 km it begins to spread or diverge. As long as surface convergence and height divergence are in balance, the surface pressure in the center does not change.

1.4 METEOROLOGICAL FACTORS

Vertical air flow and atmospheric stability

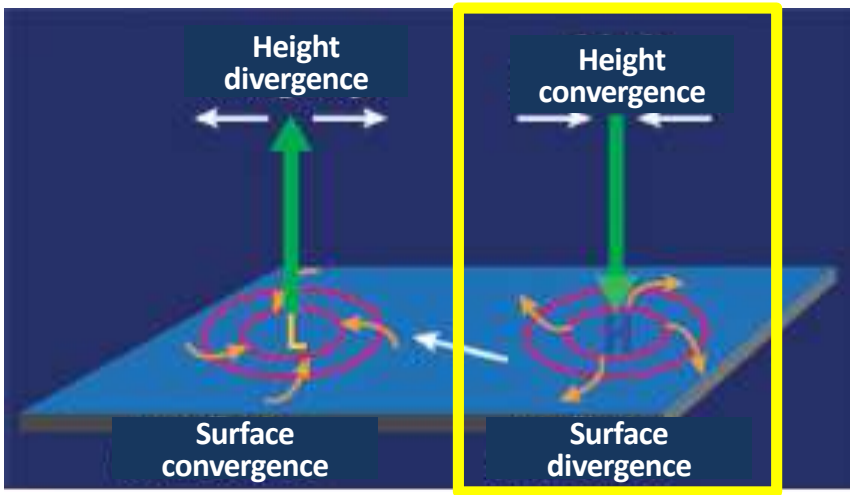


The influence of air pressure and vertical air flow on the wind

As the height divergence becomes larger than the surface convergence, the surface pressure in the center decreases. Such a situation increases the pressure gradient, and with it the force of the pressure gradient which enhances the strength of the surface winds.

1.4 METEOROLOGICAL FACTORS

Vertical air flow and atmospheric stability



When high pressure (anticyclone) is found in the center of an area, surface winds are centered outwards (surface divergence). In order to equalize the air pressures, convergence occurs - lowering the air from the height to the surface.

With high currents in cyclone areas the air will be cooled and condensed, and descending in the anticyclone areas will heat up and overcome the brightly weather.

1.4 METEOROLOGICAL FACTORS

Adiabatic change of temperature

An adiabatic temperature changes is an essential factor in determining the stability of the atmosphere.

In thermodynamics, adiabatic process is a process that takes place without the exchange of heat with the environment.

The term "adiabatic" literally means the absence of heat transfer. Generally, adiabatic processes cause a drop or rise in the temperature of the system.

Adiabatic cooling and adiabatic air heating are adiabatic processes in the atmosphere.

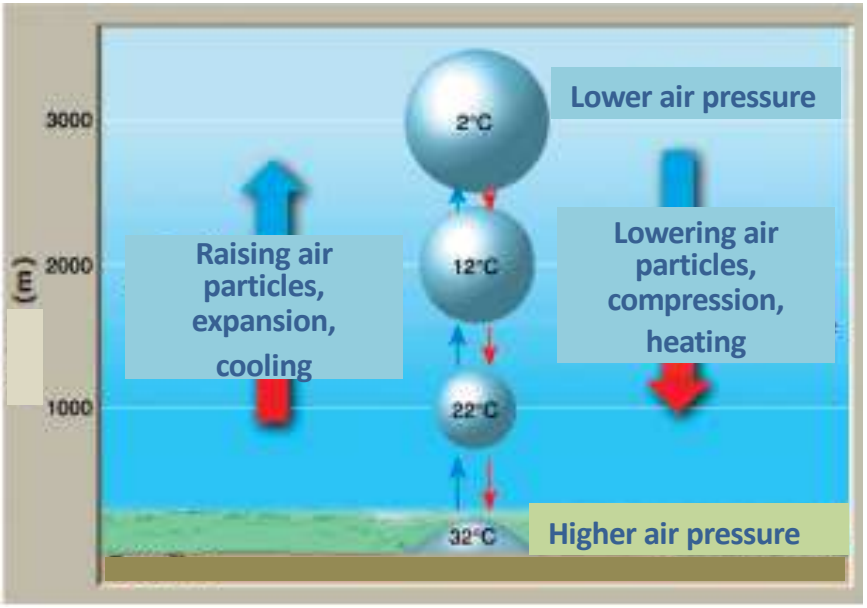
1.4 METEOROLOGICAL FACTORS

Adiabatic change of temperature

When it is dry or moist air (but not saturated with water vapor) adiabatic rises, its temperature falls adiabatic. This dry air drop is 10°C every 1 km uphill.

Value of temperature drop in air at 1 ° C of 100 m height difference is called dry adiabatic cooling rate.

Dry adiabatic rate (δa)

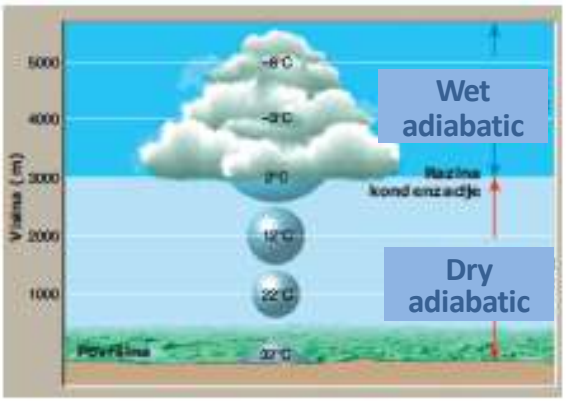


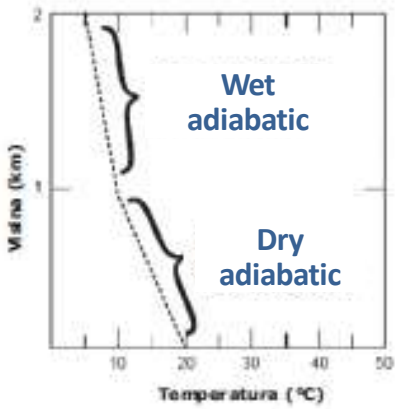
1.4 METEOROLOGICAL FACTORS

Adiabatic change of temperature

By lifting and cooling the moist air particles away from the dew, the water vapor, which particle of air contains, begins to condense or sublimate. This releases a large amount of latent heat which reduces further cooling of frequent air.

As a result, the rising air particle temperature does not fall further by 1 ° C to 100 m, but by about 0.5 to 0.7 ° C per 100 m. In this case, the air is said to cool down by wet adiabatic and the temperature changes to the wet adiabatic rate. The height at which the rising air temperature rises to the dew point is called the condensation level.





Dry adiabatic and wet adiabatic rate

1.4 METEOROLOGICAL FACTORS

Atmospheric stability

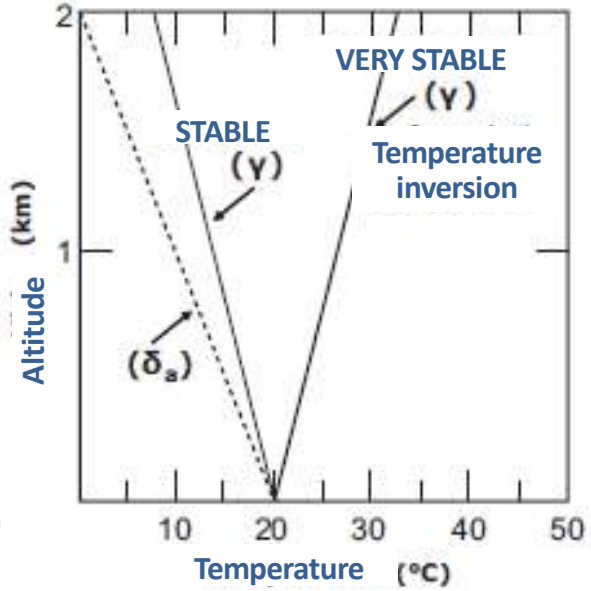
Depending on the vertical temperature gradient, the atmosphere can be located in one of the three equilibrium states:

- **stable**
- **unstable**
- **neutral**

1.4 METEOROLOGICAL FACTORS

Atmospheric stability

The atmosphere is stable when the vertical gradient of the temperature (γ) is lower than the adiabatic rate (δa), ie less than 1 ° C to 100 m in height difference. Stability is special when there are inverse layers in the atmosphere. In a stable atmosphere, weak horizontal flows and vertical downflows can occur, but vertical airflows can not occur from Earth's surface to height. Such a case occurs in anticyclones.

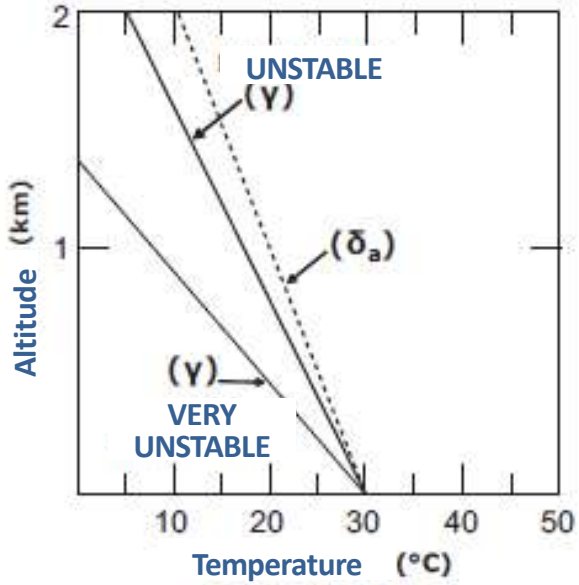


Stable conditions in the atmosphere (γ < δa)

1.4 METEOROLOGICAL FACTORS

Atmospheric stability

The atmosphere is unstable when the vertical gradient of the temperature is greater than the adiabatic, i.e. greater than 1 ° C to 100 m. Contrary to the previous case, vertical ascending streams occur in the unstable atmosphere. Such a case occurs in cyclone (depression).

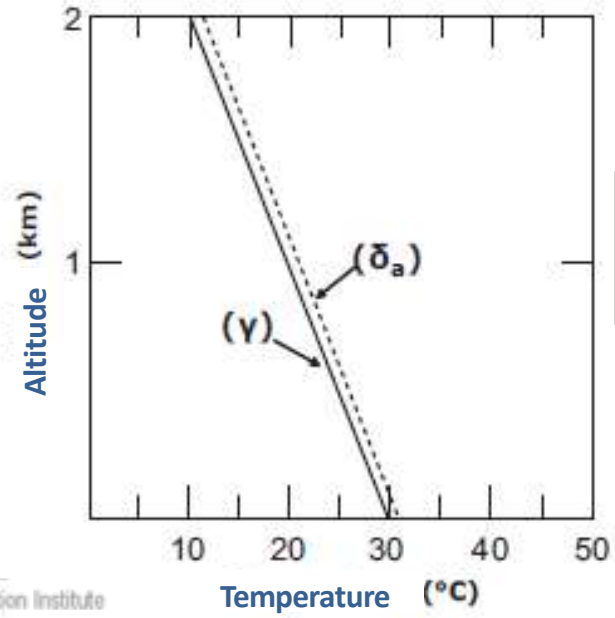


Unstable conditions in the atmosphere(γ > δa)

1.4 METEOROLOGICAL FACTORS

Atmospheric stability

The atmosphere is neutral when the vertical gradient of the temperature is equal to the adiabatic gradient, ie equal to 1 ° C to 100 m in height difference. There are no conditions for any airflow.



Neutral conditions in the atmosphere (γ = δa).

1.4 METEOROLOGICAL FACTORS

The influence of atmospheric stability on the plume of smoke

The dispersion of pollutants in the atmosphere depends on the physical condition of the atmosphere which includes:

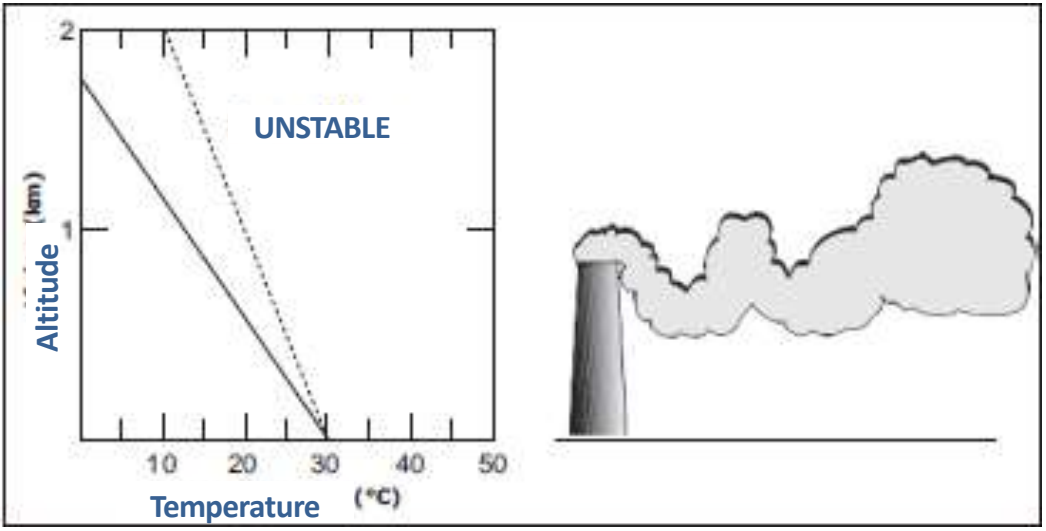
- the distribution of temperature in height
- turbulence
- the winds

One of the important indicators that characterized the state of the atmosphere is to change the temperature and air pressure with height.

1.4 METEOROLOGICAL FACTORS

The influence of atmospheric stability on the plume of smoke

looping plume occurs under strong convective conditions when the pollutant is caught in upward and downward curvature due to vertical motion of the air under unstable atmospheric conditions. **Such a case is very advantageous for the dispersion of pollutants.**

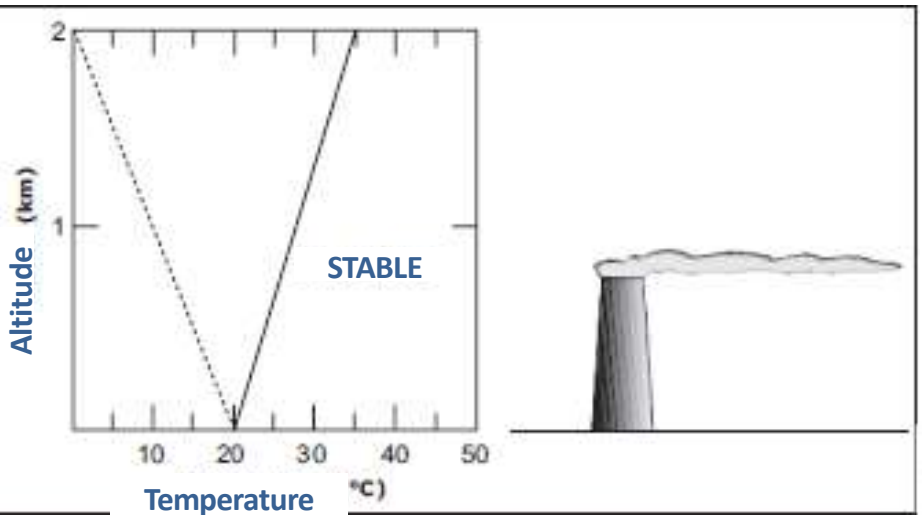


looping plume

1.4 METEOROLOGICAL FACTORS

The influence of atmospheric stability on the plume of smoke

fanning plume **occurs under stable conditions in the atmosphere. Viewed from the side is a very thin shape with barely visible conical spread, while viewed from the top or bottom there is a form of flake extending from the top of the chimney. Since there is no atmospheric motion, the smoke spreads very slowly and because of the high chimney height it does not have to touch the ground for several kilometers. Often occurs in early morning during the temperature inversion.**

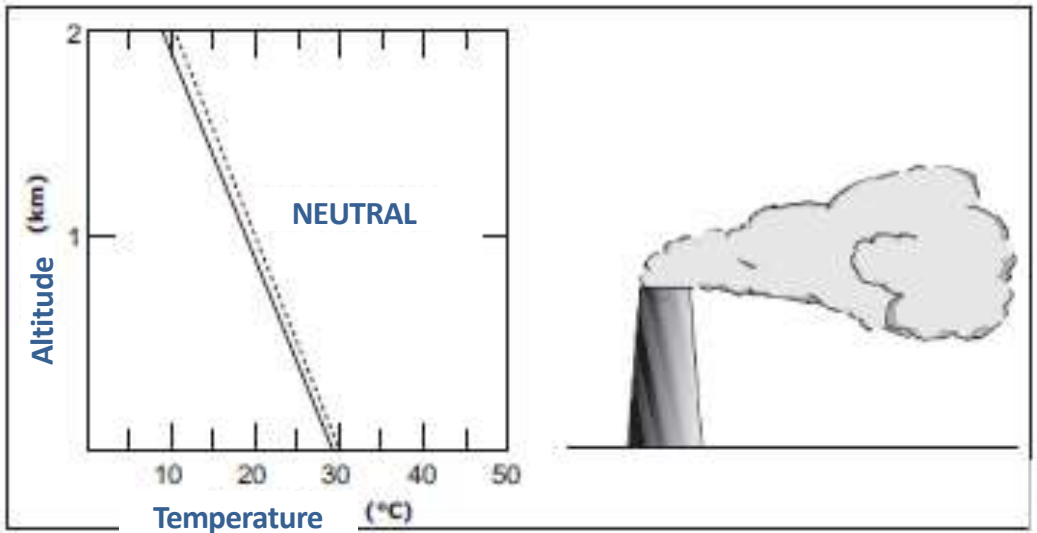


fanning plume

1.4 METEOROLOGICAL FACTORS

The influence of atmospheric stability on the plume of smoke

coning plume **is the basic shape of the smoke path under neutral and slightly unstable conditions. Such conditions occur for cloudy days. The smoke spreads as a chimney-shaped cone. Under such conditions, concentrations of pollutants in the air vary slightly.**



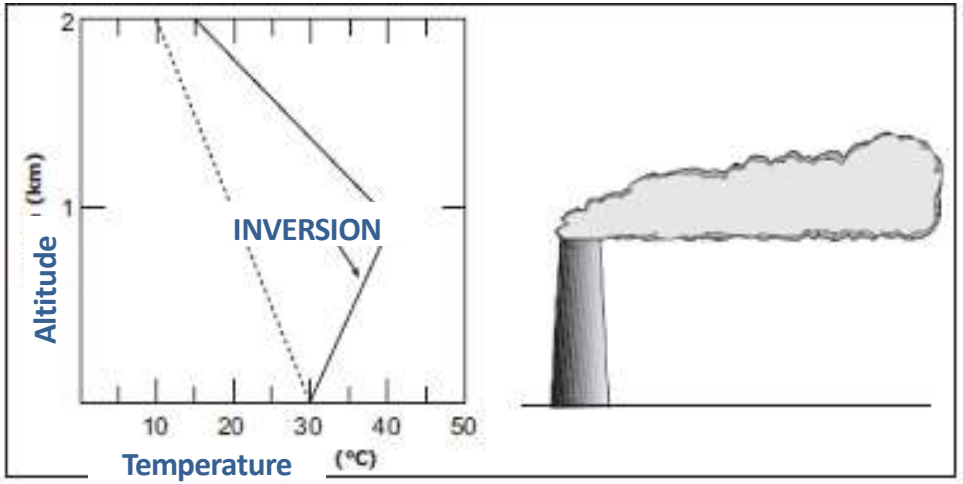
coning plume

1.4 METEOROLOGICAL FACTORS

The influence of atmospheric stability on the plume of smoke

lofting plume is created by releasing smoke into the atmosphere whose lower part is in inversion, and above it there is an unstable layer.

Temperature inversion is a barrier to vertical air mixing which negatively affects the dispersion of pollutants.



lofting plume

1.4 METEOROLOGICAL FACTORS

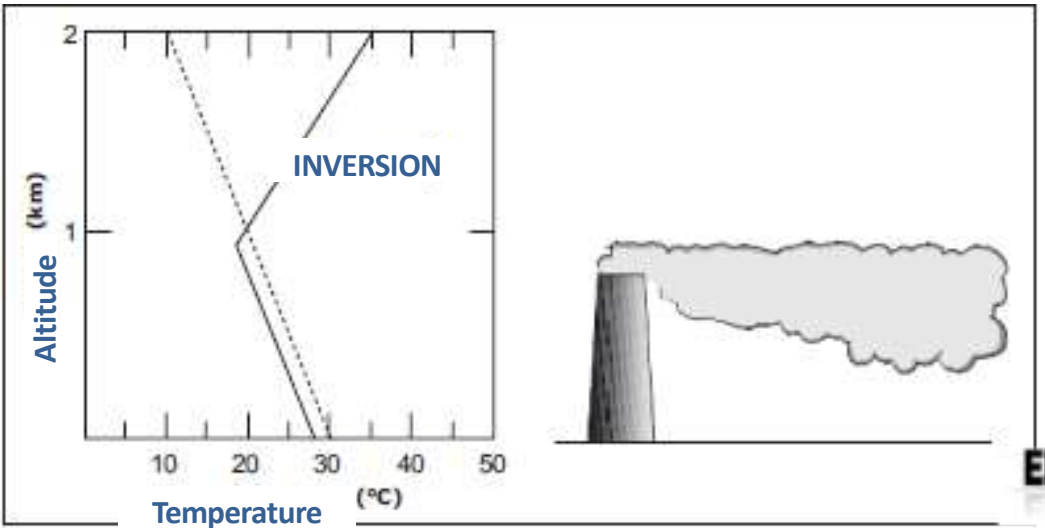
The influence of atmospheric stability on the plume of smoke

fumigating plume occurs when the inverse layer is above the smoke center and the unstable layer beneath it. **As a result, the smoke is dispersed downward causing an increase in ground level concentrations of pollutants.** A fumigating plume occurs every day when the night inversion begins to surface with the morning heat of the sun when the lower stable layer in less than one hour becomes very unstable.

1.4 METEOROLOGICAL FACTORS

The influence of atmospheric stability on the plume of smoke

In the case of increased cloudiness, the transition from stable to unstable, can last for hours, while maintaining increased high concentrations of pollutants at the Earth's surface.



fumigating plume

1.4 METEOROLOGICAL FACTORS

In the end we can conclude that knowledge of the underlying processes in the atmosphere is of utmost importance for making conclusions about transport and spread of pollutants in the air.

EKONERG Energy Research and Environmental Protection Institute

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THANK YOU FOR YOUR ATTENTION !

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