Precipitation

Rain

Precipitation includes all forms of additional water, in the liquid or solid state, that fall or form on the Earth's surface.

They can be subdivided into direct precipitation, such as rain, snow and hail and occult precipitation, such as dew and frost (see Image), that do not derive from clouds but form directly on contact with the Earth's surface.

Liquid precipitation, or rain, takes place when drops of water present in a cloud grow bigger and bigger until they are too heavy to remain in the cloud and therefore fall to the ground.

The mechanisms by which the cloud drops grow bigger are several: by absorbing water in an over-saturated atmosphere or, specially by coalescence, that occurs when drops collide against each other on falling.

The limit that separates cloud drops from rain drops is around 100 micron, but generally rain drops are much bigger, at times greater than 2000 micron.

Snow

Snowflakes are aggregations of crystals formed in the clouds directly from water vapour condensation, at a temperature below 0°C. Unlike what may commonly be thought, water vapour and low temperatures alone are not sufficient to form snow crystals. What must not be missing is dust, without which the molecules of water vapour are unable to aggregate and form snow crystals. When it is newly formed, a crystal has the shape of a column with a hexagonal base. Then, as it captures other molecules of water, it changes appearance and takes up one of the infinite and most varied shapes that are present in nature. In some cases the crystal grows more in height than in width and needle shaped crystals are formed. In other cases the opposite occurs and flat hexagon shaped crystals form. From the six angles of the original hexagonal prism, an equal number of arms can branch out giving origin to spectacular shapes (**dendritic growth**). Each crystal has its history, from its point of origin to when it falls, it crosses different areas of the atmosphere where temperature and humidity vary, and these are the principal factors that influence the shape of the crystal. Furthermore each crystal is formed by billions of molecules of water that aggregate in an unpredictable manner. It is for this reason that it is true when we say that there are no identical crystals!

Snowflakes are air-cleaners

Many scientists have carried out researches on snow crystals. One of the first to do so was Descartes who published a description of the morphology of snow crystals. Today the mechanisms that form the crystals are still not really clear. It is still not clear why water vapour molecules aggregate with an already existent crystal favouring the sides of the prism, its bases or its angles, depending on the temperature and humidity. The scientists' principal aim is to understand why snow is the best air "cleaner". Of all the polluting substances which are deposited on the ground, 90% is trapped by snow flakes and crystals. These substances form snow aggregation nuclei and are enclosed within the crystal when it forms, and are deposited on the ground with the snow. Some scientists believe that understanding these mechanisms could be useful to create more efficient anti-pollution filters than those currently in use.

Hail

Connected to thunder clouds, hail is made up of practically spherical masses of ice. Each hailstone is made up of hundreds of ice crystals, in alternate transparent and translucent layers due to the presence of air bubbles. The transparent crystals form slowly in the inferior portion of a cumulonimbus, that is characterized by higher temperatures, while the opaque crystals are typical of the superior portion, where the lower temperatures cause the rapid formation of crystals that trap air bubbles as they grow. The alternate layers of each hail stone indicate that the strong vertical currents and the turbulence present within a cumulonimbus can transport the hailstones from one portion to the other of the cloud before they fall to the ground. In Italy, the dimensions of the hailstones generally do not exceed a couple of cm, but in tropical countries hailstones can reach sizes greater than 10 cm, up to a maximum of 20 cm!

Fog

Fog is a sparsely dense not very thick layer of cloud that forms on contact with the ground in particular meteorological conditions. Generally the drops of water in a fog are smaller and less numerous than in a cloud, for this reason fogs are less dense and more transparent than clouds.

Fogs form when there is a difference in temperature between the ground and the air above it. Radiation fog forms after sunset,when the temperature of the ground decreases, provoking a slow cooling also of the air above. If the temperature drops below dew point, a fog forms. Generally the formation of fogs is favoured by the presence of stretches of water that provide water vapour to the air, thus making it more humid.

Advection fog, instead, forms when the wind brings humid warm air over colder stretches of land, or on the contrary, when cold air rests above a warmer stretch of water, such as the fogs that form over the North Sea , where warm humid air, that moves following the Gulf Stream, comes into contact with the cold waters of the North Sea, or along the coasts of Peru and Ecuador, where, on the contrary, the fog forms due to the contact of the cold waters of the Humboldt current and the hot humid equatorial air. With a similar mechanism also coast (sea) fogs form, these can be seen in the morning along the coasts and dissolve rapidly during the course of the morning.

Persistent fogs, that are typical in the winter season in the Po valley, instead, are due to cold air that descends into an anticyclone area: if there is humid air near the ground, due to the presence of sheets of water or due to the humidity in the soil (for example the humid soil in the paddy fields), the humidity in the atmosphere condenses giving rise to heavy fog that persists as long as the high pressure conditions continue

Dew

When the ground, dispersing heat by radiation, reaches dew point, the air that is directly in contact with it, condenses and deposits drops of water directly on the ground, and on all the surfaces the air comes into contact with, thus forming dew.

Dew supplies a quantity of water that can be important in some particular situations: where there is no direct precipitation, the vegetation however receives an amount of water that is sufficient for its vital processes. For this reason these are known as occult precipitations, i.e. they are not directly visible. It is not easy to evaluate their quantity, but these precipitations must be taken into account when calculating the ideological balance of the water cycle. In fact dew is partly absorbed by the ground, and a part of it evaporates during the day, and thus becomes part of the water-cycle once again. This type of water supply is fundamental for the survival of plants and animals in arid, semi-desert zones.

Frost

Frost forms at temperatures below 0°C, due to the dew that freezes or due to direct precipitation of small ice needles.

Rime, which is known as galaverna in a dialect of Northern Italy, is a particular form of frost, characterized by large needle-shaped ice crystals which may be transported by the wind, and cover all the surfaces following their contours in their finest detail, as for example blades of grass, twigs, electric wires and antennas.

Frost too, belongs to the category of occult precipitations. It can melt and evaporate during the course of the day, or it may remain on the ground for various days, depending on the temperatures. If frost deposits on snow and is then covered by snowfall, a level of ice crystals may form within the layer of snow that is not very coherent, and may cause the release of slab avalanches.

The weather

Weather, from a meteorological point of view, indicates the set of atmospheric phenomena that take place at a particular moment in a part of the Earth. Some phenomena have a strictly local influence, limited to extremely restricted areas, while others involve entire regions. Atmospheric phenomena are characterized by great variability and small local variations can contribute in making the weather evolve into situations completely different from those foreseen.

Air masses

Air masses, in a meteorological sense, are volumes of atmosphere with uniform temperature, pressure and humidity.

Air masses can be subdivided into six big categories: Arctic air (very cold and very dry), Continental Polar air (cold and dry), Maritime Polar air (cold and humid), Continental tropical air (hot and dry), Maritime tropical air (hot and humid), Equatorial air (hot and very humid).

Perturbations

Perturbations are all climatic and meteorological events that, in some way, disturb the state of equilibrium the atmosphere is in. Since it is a dynamic equilibrium, that varies continuously, it is difficult to establish what exactly a perturbation is when the atmosphere is in a 'normal' state, hence the term perturbation today is synonymous with events that bring on bad weather, precipitation or atmospheric events that are in some way unpleasant or threatening for man. In general, from a meteorological point of view, a perturbation is created every time there is interaction between air masses at different temperatures and pressure, even though this does not necessarily mean bad weather and precipitations.

Fronts

A front in a meteorological sense is the zone of contact between air masses with different density, temperature and humidity. The frontal band is the area in which two air masses come into direct contact, the area in which energy exchanges take place and where the more intense atmospheric phenomena are produced. Generally, a front appears as a more or less regular surface, with a low angle , slightly inclined, and it generally forms a curved line on the horizontal plane. Meteorologists identify three types of fronts: cold, hot and occluded.

When hot or cold fronts form, the condensation processes free thermal energy and this contributes to creating areas at different temperatures, triggering off local circulation and mixing and contributing to a further increase in the instability of the air masses.

The front of a perturbation, in the initial phases of its formation, is generally related to the so-called wind front, that is associated to the progress of cold masses of air that descend from the perturbation. At times the wind front is made visible by dust clouds that rise from the ground (as in dust storms) or by the condensation front that gives rise to the formation of spectacular arc-shaped clouds on the same level of the perturbation front.

The presence of mountains along the course of the front can bring about variations and deformations of various kinds that can make the perturbation evolve in an unpredictable way.

Storms

Perturbations that bring storms are formed when there is a collision between two air masses at different temperatures or when the excessive heating of the ground, along with a high level of humidity, brings about the formation of masses of warm, humid air. The mechanism is the same as that which leads to the formation of fronts and cloud systems (ascent, cooling and condensation), but owing to the great differences in temperature, the phenomenon is more intense and 'energetic'. Storms are therefore typical of warm, humid regions, such as tropical and subtropical zones, or our latitudes during the summer months. The mechanisms that lead to the formation and evolution of storms were studied at the end of the Forties at the University of Chicago in a research programme called Thunderstorm Project, that brought to the construction of a clear picture regarding these atmospheric phenomena.

The indicators connected to a storm cloud (winds, precipitation even including hail, lightning) can be very violent and destructive and in particular conditions storms can evolve into tornadoes or whirlwinds.

Cyclones and hurricanes

Around low pressure areas, air circulation generates a depression vortex called a cyclone. The circumstances that lead to the onset of a cyclonic circulation are always the same: the low pressure centre attracts air from the surrounding areas with an anticlockwise movement in the Northern Hemisphere and a clockwise movement in the Southern Hemisphere.

But cyclones are not all the same. Why are some violent and unexpected, real catastrophes? Why do some last for months? Why are others relatively 'calm' and do not cause damage?

In theory, the greater the difference in pressure, the greater the violence and speed of the winds and therefore the more destructive the cyclone will be. However, generally, the differences in pressure are relatively small and similar in each

vortex (normally, a couple of tens of mb). It all depends on the size of the low pressure area. Considering that the difference in pressure is constant, if the low pressure area is extended, the pressure gradient will be low and the winds relatively 'slow'; if, on the other hand, the area is restricted, the high pressure gradient will provoke violent, very fast-moving winds which in some cases can exceed 250 km/hr, reaching up to 400 km/hr like in tornadoes or whirlwinds.
Therefore there will be considerable differences between the power of a so-called extratropical cyclone, like those that occur in our latitudes and that are extended over areas with a diameter of thousands of km, and that of a tropical cyclone, or of a hurrican, that rarely has an extension that exceeds hundred kilometres. Even more destructive, but on a strictly local scale, are whirlwinds and tornadoes (from the Spanish word for 'vortex'), or their marine equivalent, the waterspouts, that generally have dimensions of a couple of hundreds of metres: these are the most violent meteorological phenomena even though they are not the most destructive because fortunately they are small and they last a very short time.

Tornadoes

Tornadoes form evolving from cumulonimbus storm clouds when the atmospheric conditions are particularly humid. They begin with the downward shear of a part of the cloud, thus forming a funnel-shaped cloud that is the first sign of the birth of a tornado. The funnel cloud descends gradually towards the ground: if it reaches the Earth's surface, it becomes a tornado. The dimensions of the funnel cloud are indicators of the strength of the tornado, and range from 15 m to a couple of kilometres in diameter. Along the surface of the funnel, air is rotating rapidly, with a spinning ascending motion. Tornadoes move over the Earth's surface at a speed that can reach 120 km/hr, but the speed of the rotating winds within a tornado can reach 450 km/hr with ascending wind speeds of 290 km/hr. The pressure inside the vortex can be practically reduced to zero, and it is for this reason that tornadoes behave like enormous 'vacuum cleaners', that collect whatever they find along their path: houses, cars, trees, livestock, whatever happens to be on the course of a tornado gets uprooted and flung upwards. Just like in tropical cyclones, inside the vortex instead, the air is calm and practically motionless. There are several accounts of people who found themselves miraculously safe and unharmed inside the vortex of a tornado, or of livestock that was lifted up and then deposited unhurt on the roofs of buildings, or of electric and telephone cables completely coated with hay and of other 'curious' facts.
As the destructive energy gets depleted, the funnel of the tornado slows down its run, the winds inside decrease in speed and the funnel changes shape taking on a flexuous, snake-like form, a clear indication that the energy of the tornado is running out.
Tornadoes are surely the most destructive meteorological events, but generally the devastations take place on a reduced scale, in other words they bring about an almost total trail of destruction in their wake but over relatively restricted areas, unlike hurricanes. Generally, tornado damage paths range from 90 to 1,500 m. On average, a tornado dissipates within 15 minutes and covers around 15 kilometres, but some of the bigger clouds can travel even 400 km and last for several hours.

Whirlwinds

Whirlwinds are similar to tornadoes, but are decidedly smaller and with less energy. When they evolve from storm clouds, they behave like small tornadoes and can be quite destructive. Whirlwinds, also called dust devils, with smaller dimensions and minor energy, usually form in very warm and dry air conditions in desert regions or in the plains and are not associated with clouds or precipitation. These vortices are triggered off by convective phenomena caused by intense heating of the ground. 'Dry' whirlwinds of this kind are very frequent in the SW of the United States, where generally their size is limited, and they cause no damage. A game that American children living in this area often play, is to try and chase the whirlwind and enter inside the vortex: when they succeed in doing this the convective process gets interrupted and the whirlwind vanishes.

Waterspouts

When a tornado or a whirlwind pass over a body of water (the sea, but also a lake) we speak of waterspouts or twisters. They usually dissipate immediately, the minute they move onto land, but in some cases they can penetrate inland for several kilometres. The vortex sucks in air and water on passing, hence its sides are made up of a 'wall' of rapidly rotating water: in this case a curious phenomenon may take place – a rain of fish, frogs and other aquatic animals that the tornado has collected on its path and that are abruptly abandoned when the phenomenon ceases.

A thunderstorm breaks

The main atmospheric phenomenon associated with a thunderstorm is surely the rain, that often arrives in the form a sudden violent downpour. It has been calculated that only 20% of the humidity accumulated in the thundercloud is actually returned in the form of rain. Often precipitation may take the form of hail, that forms when the temperatures inside the cloud allow the formation of ice crystals.

Also the wind is a phenomenon that can have a particularly violent nature during a storm, and it can evolve, at times, into a tornado or hurricane.

Surely the most impressive phenomenon of a thunderstorm is the lightning, electric discharges that are produced within the cloud, between different clouds, and between the clouds and the ground. Thunder is the "noise" produced by the movement of air provoked by the electric discharge and therefore is only a "collateral" manifestation.

Lightning

Lightning is one of the most typical and characteristic manifestations of thunderstorms. Lightning is visible in the form of electric discharges that originate from the thundercloud and hit the ground, however the phenomenon is much more complex, and since it takes place at the speed of light, it is so rapid that we are unable to understand it immediately.

Lightning is an electric discharge inside a storm system. Lightning can occur within a cloud, between adjacent clouds, or between the clouds and the ground. Generally about 80% of the electric activity of a storm cell is discharged within the cloud or between two clouds and only 20% of the discharges take place between the clouds and the ground. Notwithstanding this, it has been calculated that streaks of lightning hit the ground at a rate of over 100 per second!

Above the 0°C thermocline, water in the cloud takes the form of ice crystals which have a positive charge on the surface. Instead, under the thermocline the drops of water have a negative charge. In this way within the clouds that extend vertically beyond the 0° C isotherm, strong differences in potential form between zones with opposite electric charges. Thus electric discharges are produced between the zone with the positive charge and the negative charge zone. This occurs within the cloud, but also between two clouds when zones with different electric charges come into contact.

It is slightly more complicated to explain how lightning is discharged to the ground. The Earth's surface generally has a negative charge, as also the base of the storm clouds. Electric discharges of the same sign tend to repel each other therefore, during a storm, on the Earth's surface, where the negative charges have been pushed away by the negative charges of the base of the cloud, areas with a positive charge are formed.

When charges of opposite signs accumulate, due to their reciprocal attraction, a channel of ionized air forms, which propagate from the cloud to the ground, and that is known as the stepped leader. As the stepped leader reaches the ground, from the Earth's crust a second stroke is triggered, that reaches the stepped leader before it connects to the ground: this is what we see as the main lightning stroke. Obviously this all takes place at the speed of light in only a few milliseconds, therefore it gives us the illusion that the lightning stroke travels from the cloud towards the ground. If on the ground there are concentrations of positive charges that are close to each other, a number of return strokes may leave the ground simultaneously toward the same leader, and the lightning appears in the typical shape branching downwards.

Thunder

When lightning is generated, the electric discharge produces a great quantity of heat that ionizes the surrounding air, transforming it into a plasma (gas consisting of only electrons and nuclei) at an extremely high temperature (10-15,000° C). The air all around expands violently, in a few millionths of a second, provoking the propagation of a compression wave though the air, which we hear as an acoustic wave that produces thunder.

Thunder propagates at the speed of sound (350 m/s), while lightning travels at the speed of light (300,000 km/s), therefore the sound produced by the lightning is heard with a slight delay. We can enjoy calculating the distance of a storm cloud by measuring the time-interval from when we see the lightning to when we hear the thunder. With a rather approximate calculation, dividing the number of seconds that have passed by three, we obtain the distance in kilometres.

The rainbow

The rainbow is a phenomenon that has always fascinated man, on one hand because generally it indicates that the end of a storm is near, on the other because of the sight offered by its colours. Who hasn't been charmed by the display of a rainbow, perhaps against a sky darkened by threatening stormy clouds? About rainbows there are a number of myths and legends. For the Greeks it was a visible manifestation of a messenger of the Gods, according to Northern legends, at the far end of a rainbow is a pot containing a fabulous treasure.

In reality, a rainbow is a simple optical phenomenon, caused by the refraction of white light as it passes through the drops of water: analogously to the light that passes through a prism, the sun's light that passes through a drop of water is refracted and separated into its different wavelengths. Diversely from the prism, through which we are able to see all the visible wavelengths of the spectrum at the same time, we are able to see one colour only, only one wavelength for each drop, depending on the height of the drop compared to our position, and the angle of light refraction from the drop to our eyes. Sunlight that simultaneously hits millions of microscopic drops of water is therefore refracted through each one of these (actually light is refracted twice, on entering the drop and when it passes outside). The result is that we see a series of concentric bands of coloured arcs drawn across the sky. The colours derive from the decomposition of the spectrum, that are visible at the different wavelengths, and are always in a precise order (depending on the wavelength) starting from the innermost arc with violet, indigo, blue, green, yellow, orange and red in the outermost arc.

A rainbow can be observed immediately after a downpour, when the sun breaks out between the clouds and it can be seen when the sun is behind our shoulders. A rainbow can form a complete arc from one point on the horizon to another, or only a part may be visible. At times double rainbows can also form, where one is always less brilliant and the sequence of colours is inverted, due to a complicated play of refraction and reflection inside and on the surface of the drops.

Iridescent halos and more faded rainbows with less brilliant colours may also form around the sun or the moon when these are veiled by cloud formations composed of ice needles, like the cirrus clouds. This type of rainbow can easily be seen in high mountain areas.