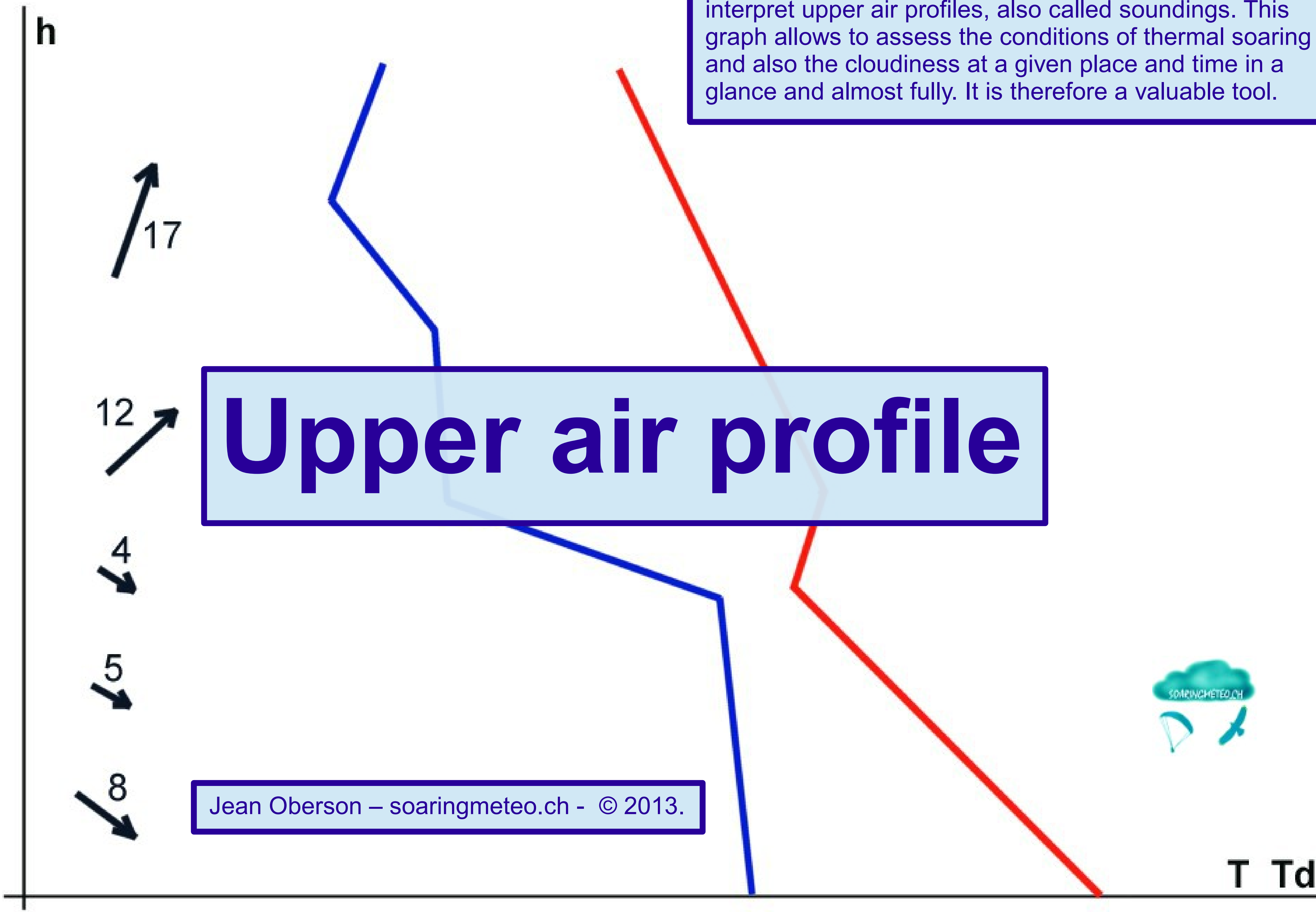
Upper air profile

The purpose of this paper is to show how to quickly interpret upper air profiles, also called soundings. This graph allows to assess the conditions of thermal soaring and also the cloudiness at a given place and time in a glance and almost fully. It is therefore a valuable tool.



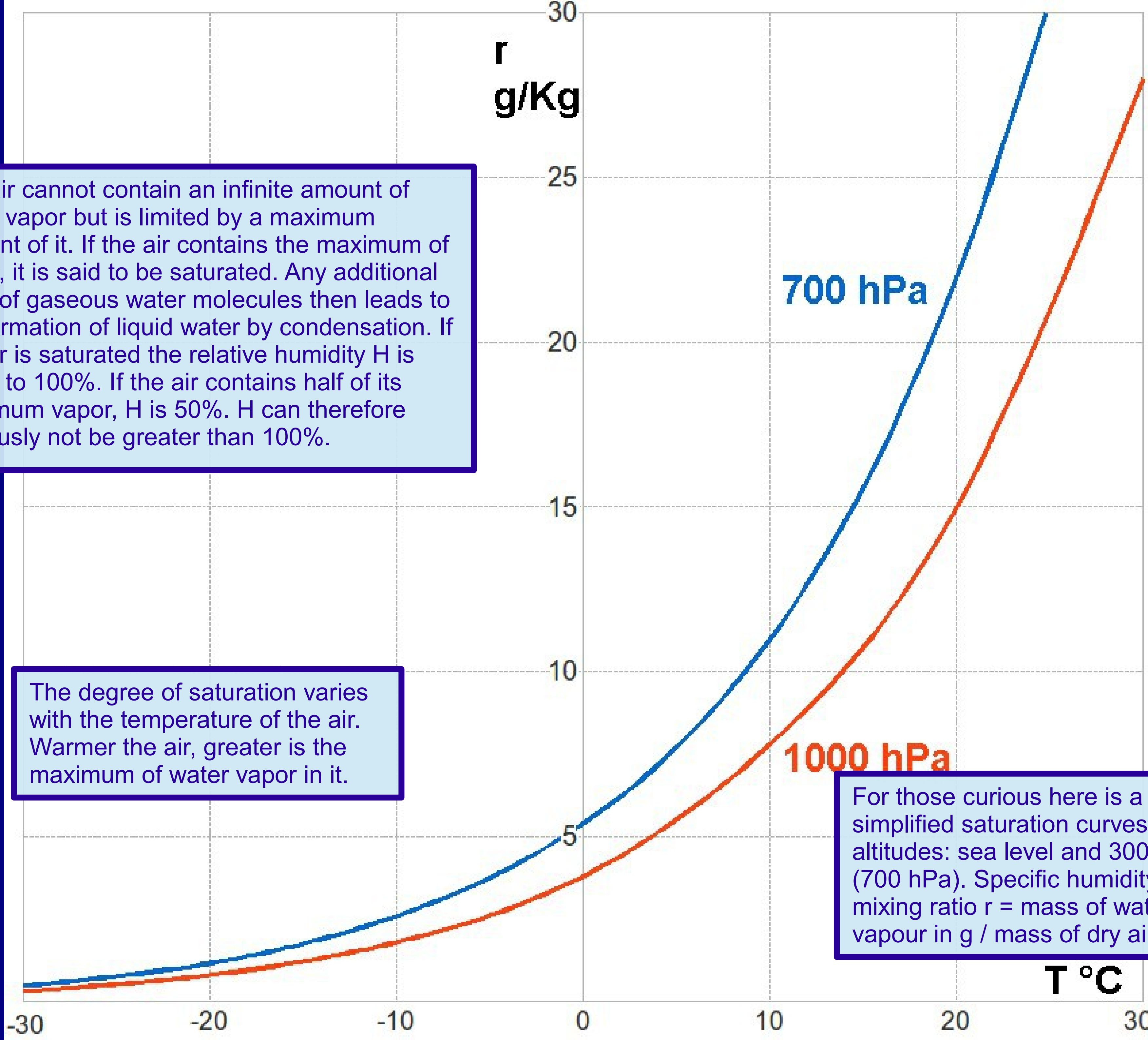
Jean Oberson – soaringmeteo.ch -

To well understand the humidity (moisture of the air) is very important to understand and use a upper air profile. A simple and practical reminder of the concept is needed.

Water is present in nature in three states: solid (ice and snow), liquid (water) and gas (steam). There is evaporation when liquid water turns to steam and condensation if the steam turns into liquid water. On land ice is present in glaciers and snowfields and liquid water in rivers, lakes and seas. But in the atmosphere, ice and liquid water are in the form of visible airborne dust as clouds or mist or in the form of precipitations (rain, snow, hail). In the atmosphere, water vapor is always present in a some amount, which varies depending on location and weather conditions, even in the Sahara.

The air moisture is the amount of water vapor in the air. Water vapor is invisible unlike liquid water or ice. It should not be confused with the cloud, fog or whitish veil of hammam which is a collection of many water liquid dust suspended in the air.

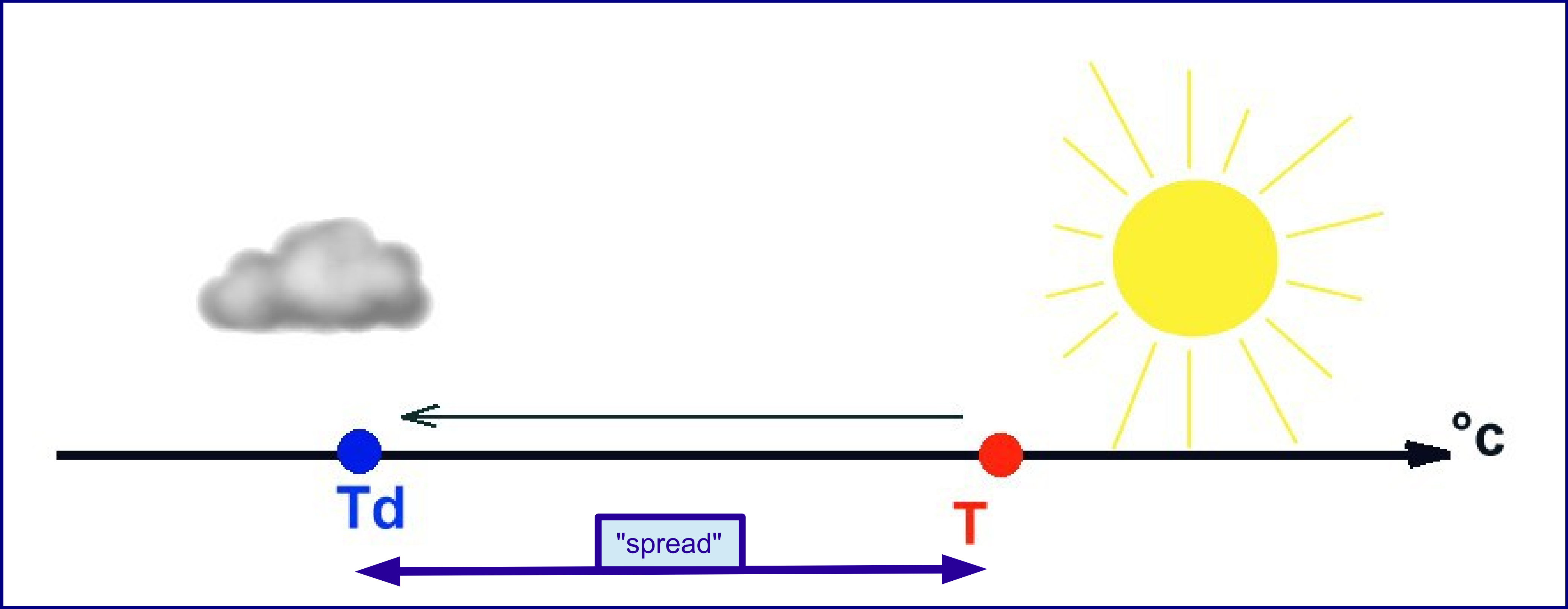
The air cannot contain an infinite amount of water vapor but is limited by a maximum amount of it. If the air contains the maximum of vapor, it is said to be saturated. Any additional input of gaseous water molecules then leads to the formation of liquid water by condensation. If the air is saturated the relative humidity H is equal to 100%. If the air contains half of its maximum vapor, H is 50%. H can therefore obviously not be greater than 100%.



The degree of saturation varies with the temperature of the air. Warmer the air, greater is the maximum of water vapor in it.

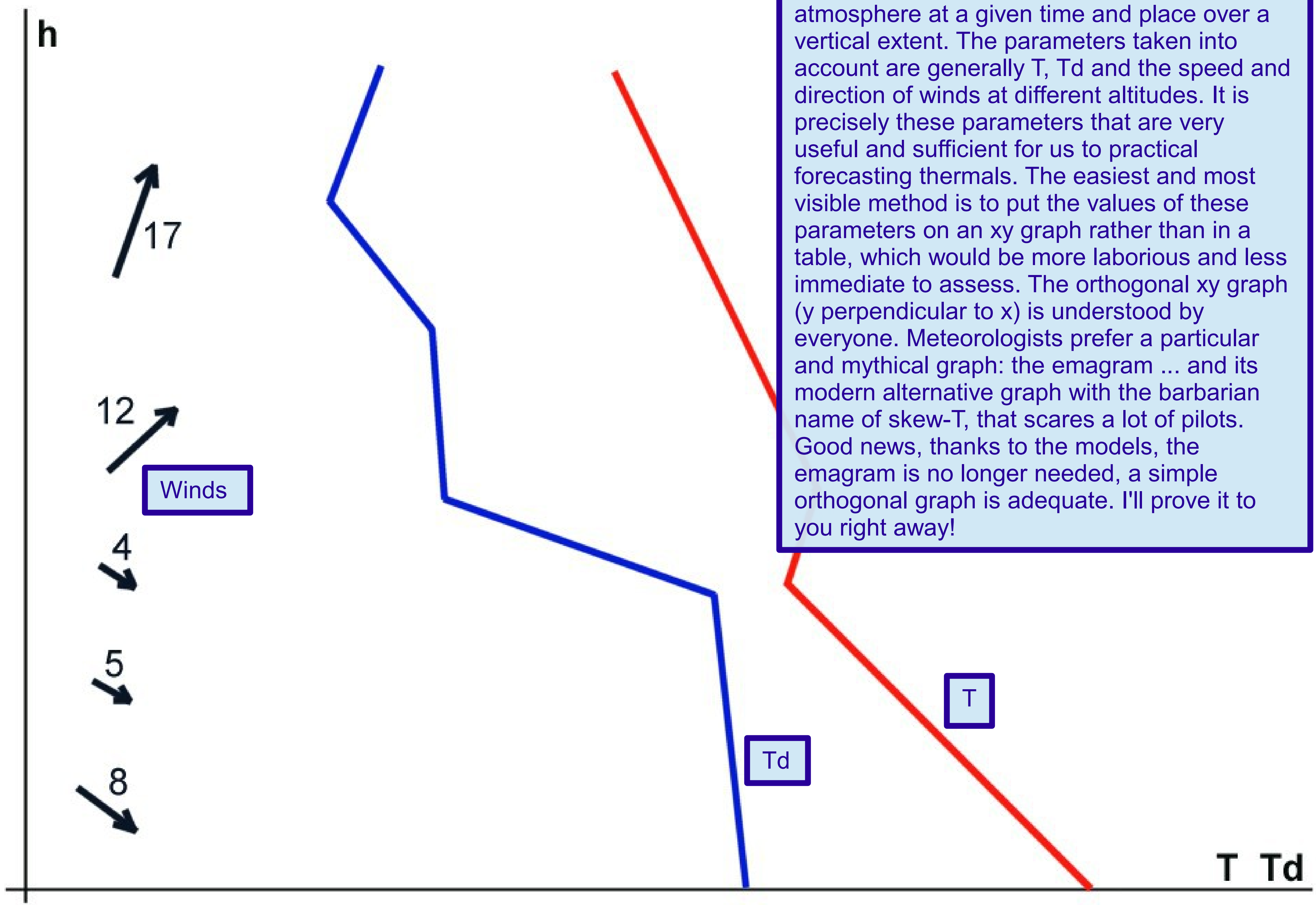
For those curious here is a simplified saturation curves in two altitudes: sea level and 3000 m (700 hPa). Specific humidity or mixing ratio r = mass of water vapour in g / mass of dry air in Kg.

For the upper air profile H is not used but another way of measuring moisture of the air: temperature dew point Td. Td is the temperature downto which a parcel of air must be lowered to be steam saturated and hence condensation to occur. In practice, the distance (difference) between the starting temperature of the air T and Td, called the "spread" gives a good idea of the humidity of the air. A "spread" of 0 °C indicates saturated air with H = 100%. A "spread" of 5-8 °C indicates moderately humid air (H = 50%), while more than 12-15 °C "spread" indicates a very dry air. Td can never be greater than T because when T = Td humidity is already at its maximum (saturation).

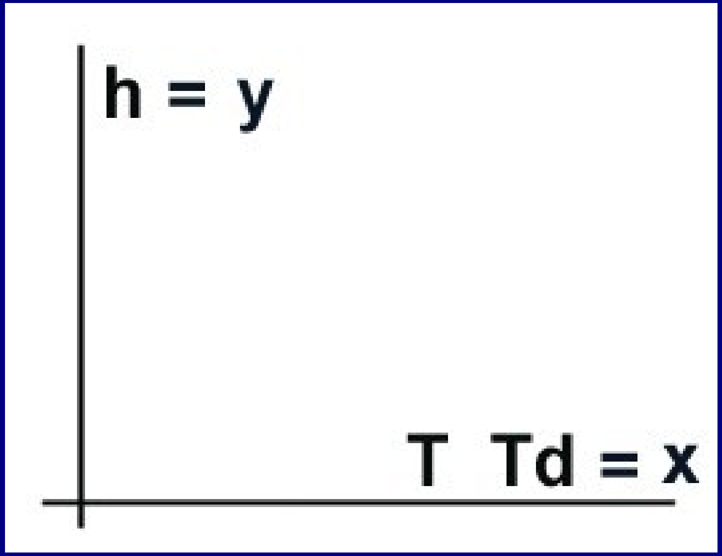


Here is a concrete example: let us take a parcel of air with a temperature of 25 °C. It is cooled. By reaching 13 °C, there is condensation phenomena (e.g. fogging). This air parcel therefore has a T = 25 ° C, a Td = 13 ° C and a "spread" = 25-13 = 12 ° C.

An upper air profile is a snapshot of the atmosphere at a given time and place over a vertical extent. The parameters taken into account are generally T, Td and the speed and direction of winds at different altitudes. It is precisely these parameters that are very useful and sufficient for us to practical forecasting thermals. The easiest and most visible method is to put the values of these parameters on an xy graph rather than in a table, which would be more laborious and less immediate to assess. The orthogonal xy graph (y perpendicular to x) is understood by everyone. Meteorologists prefer a particular and mythical graph: the emagram ... and its modern alternative graph with the barbarian name of skew-T, that scares a lot of pilots. Good news, thanks to the models, the emagram is no longer needed, a simple orthogonal graph is adequate. I'll prove it to you right away!



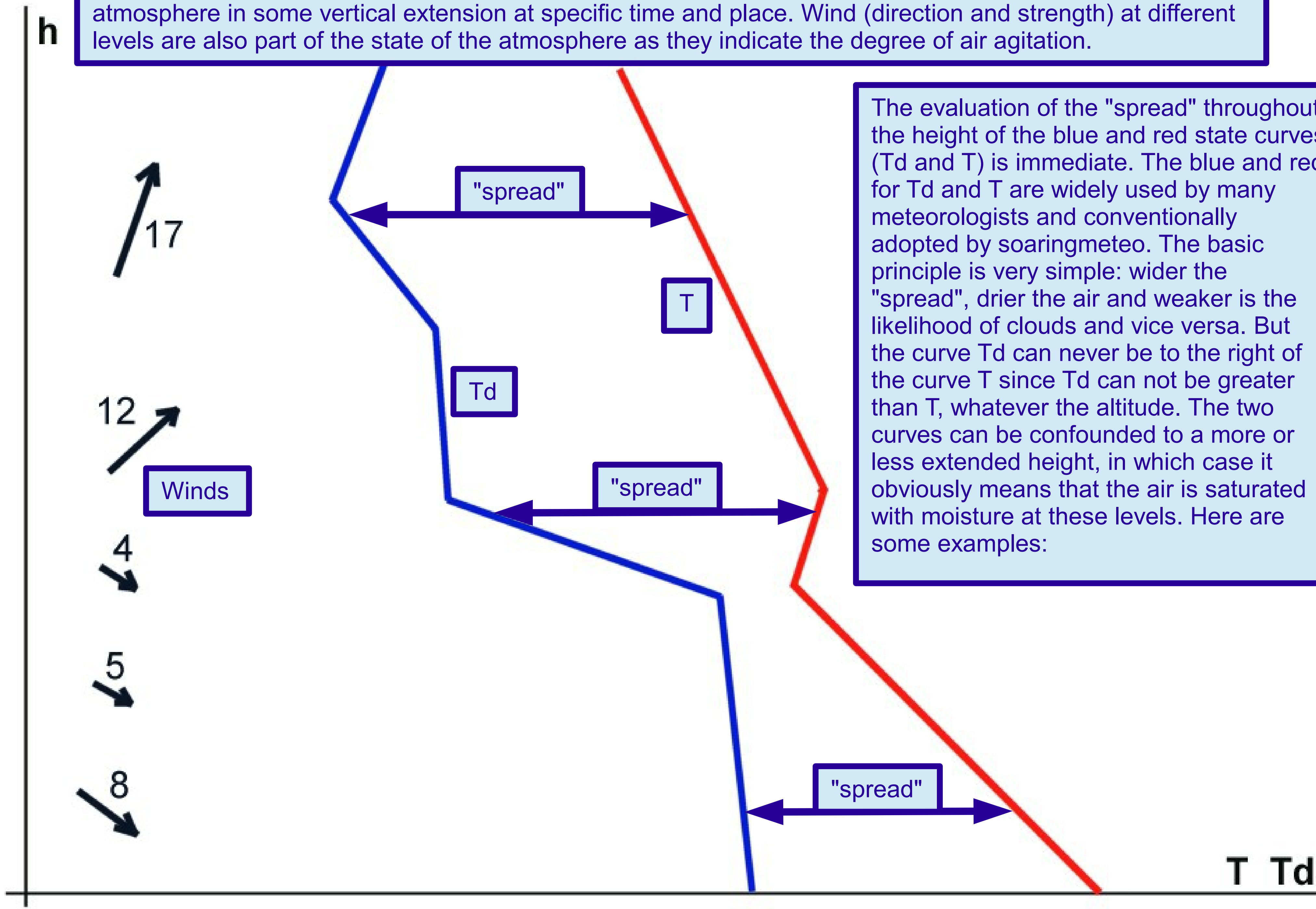
On y-axis, you can read the altitude. It is natural to measure the altitude with length units as the meter but also get used to represent you the altitude with the pressure unit hectopascal hPa (1000 hPa = 1000 millibars). You will see that it will be useful. Atmospheric pressure decreases with altitude and luckily almost linearly between 0 and 5000 m. Memorize therefore this small table. The exact value of the altitude layers of pressure varies constantly depending on the time of day, weather conditions and the season.



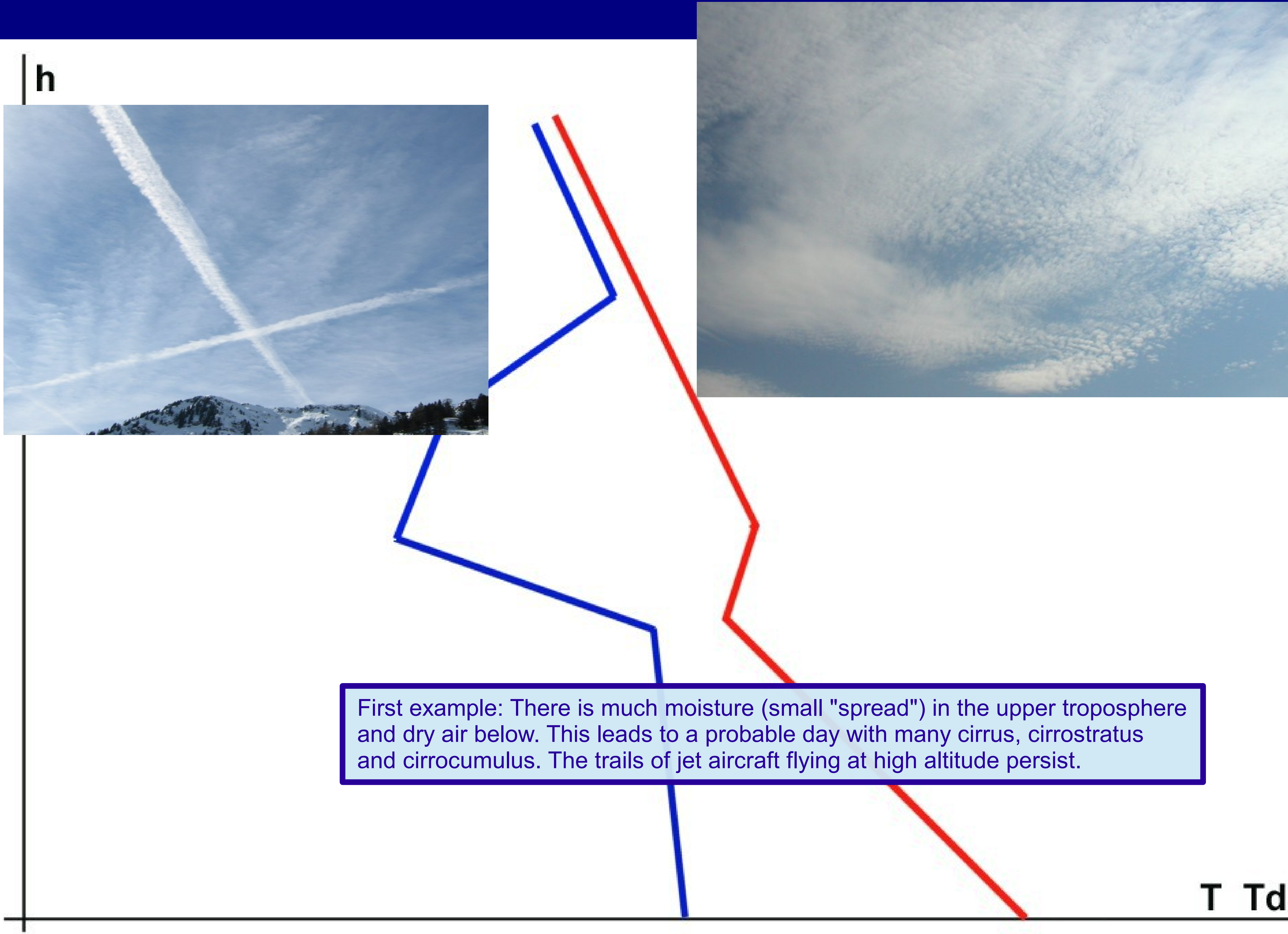
hPa	m
1000	0
900	1000
850	1500
800	2000
750	2500
700	3000
600	4300
500	5500

On x-axis we can read the temperature in °C (degrees Celsius). That is why Td rather than H is used to represent air moisture. With Td the curves of temperature and humidity have the same unit on the same x-axis.

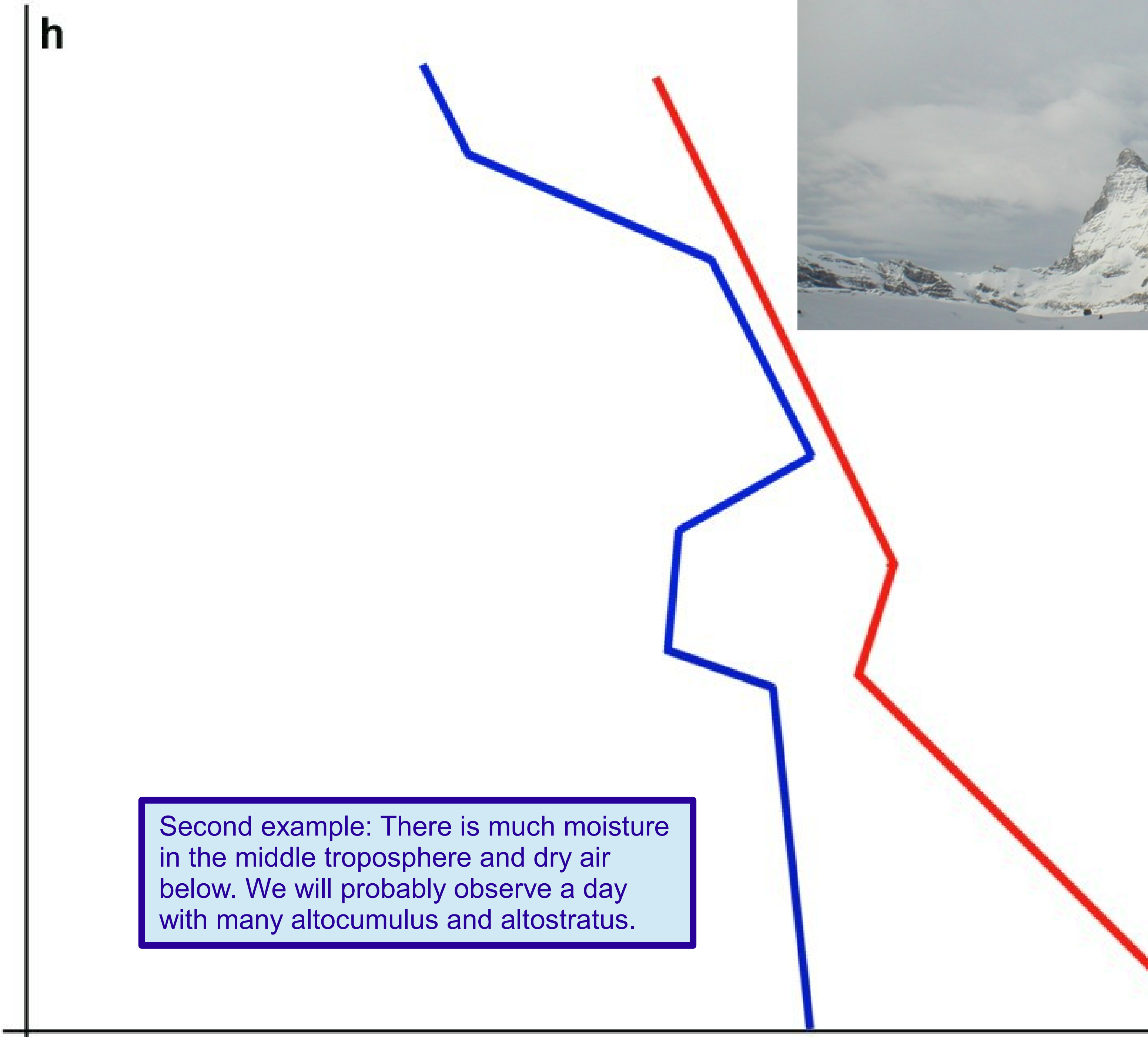
On this graph, the T and Td curves are called state curves because they represent the state of the atmosphere in some vertical extension at specific time and place. Wind (direction and strength) at different levels are also part of the state of the atmosphere as they indicate the degree of air agitation.



The evaluation of the "spread" throughout the height of the blue and red state curves (Td and T) is immediate. The blue and red for Td and T are widely used by many meteorologists and conventionally adopted by soaringmeteo. The basic principle is very simple: wider the "spread", drier the air and weaker is the likelihood of clouds and vice versa. But the curve Td can never be to the right of the curve T since Td can not be greater than T, whatever the altitude. The two curves can be confounded to a more or less extended height, in which case it obviously means that the air is saturated with moisture at these levels. Here are some examples:

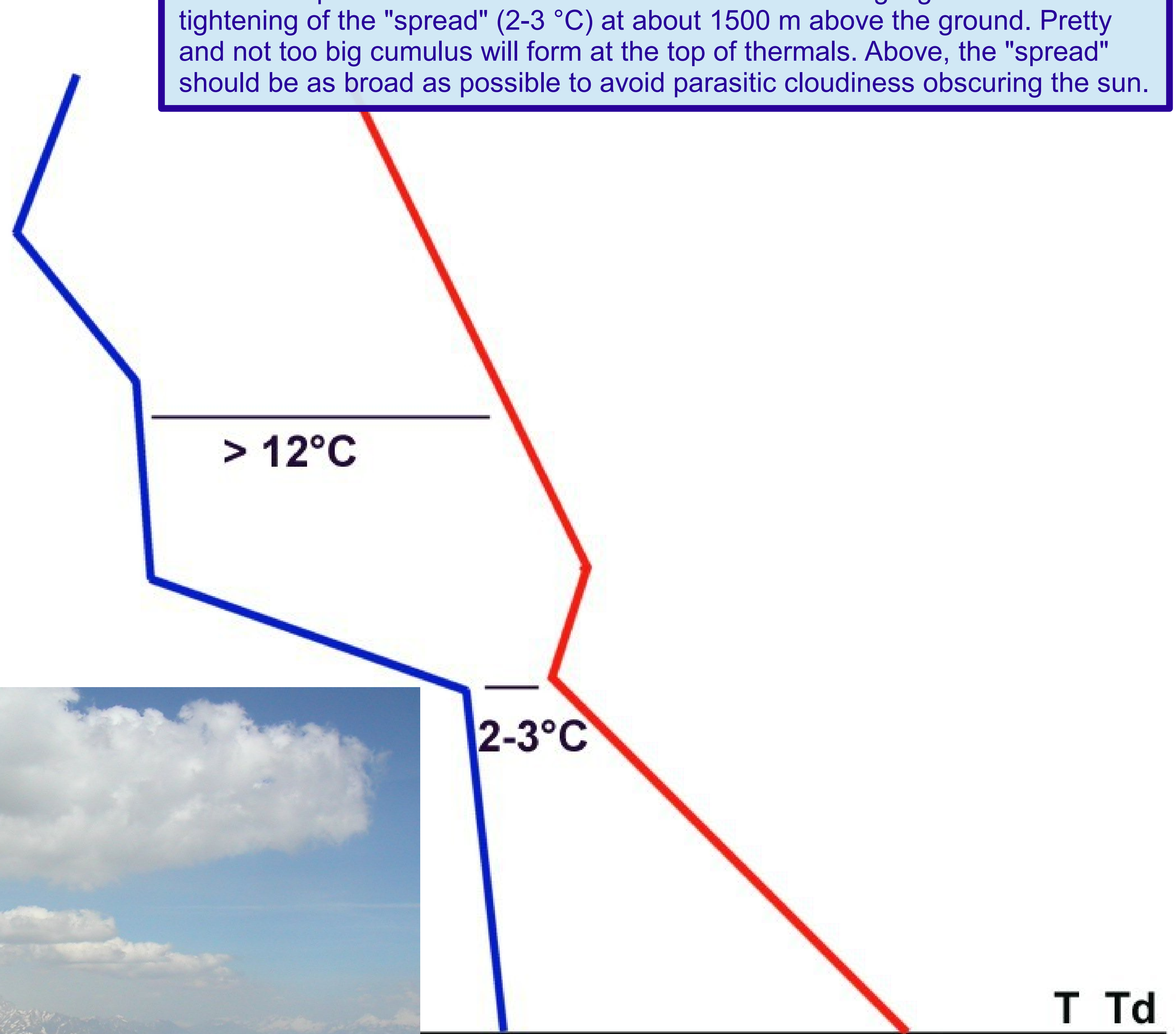


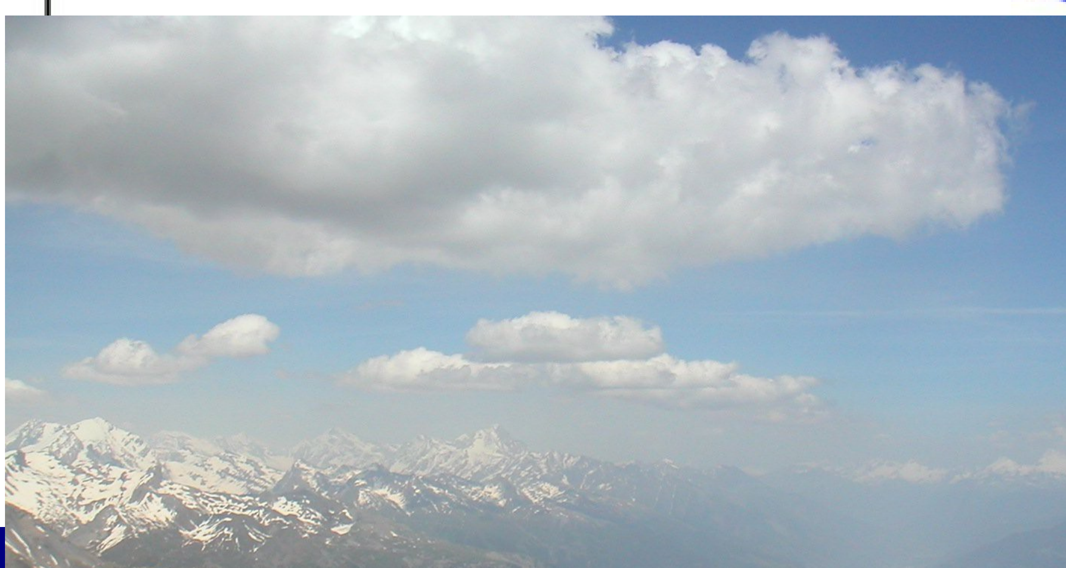
First example: There is much moisture (small "spread") in the upper troposphere and dry air below. This leads to a probable day with many cirrus, cirrostratus and cirrocumulus. The trails of jet aircraft flying at high altitude persist.

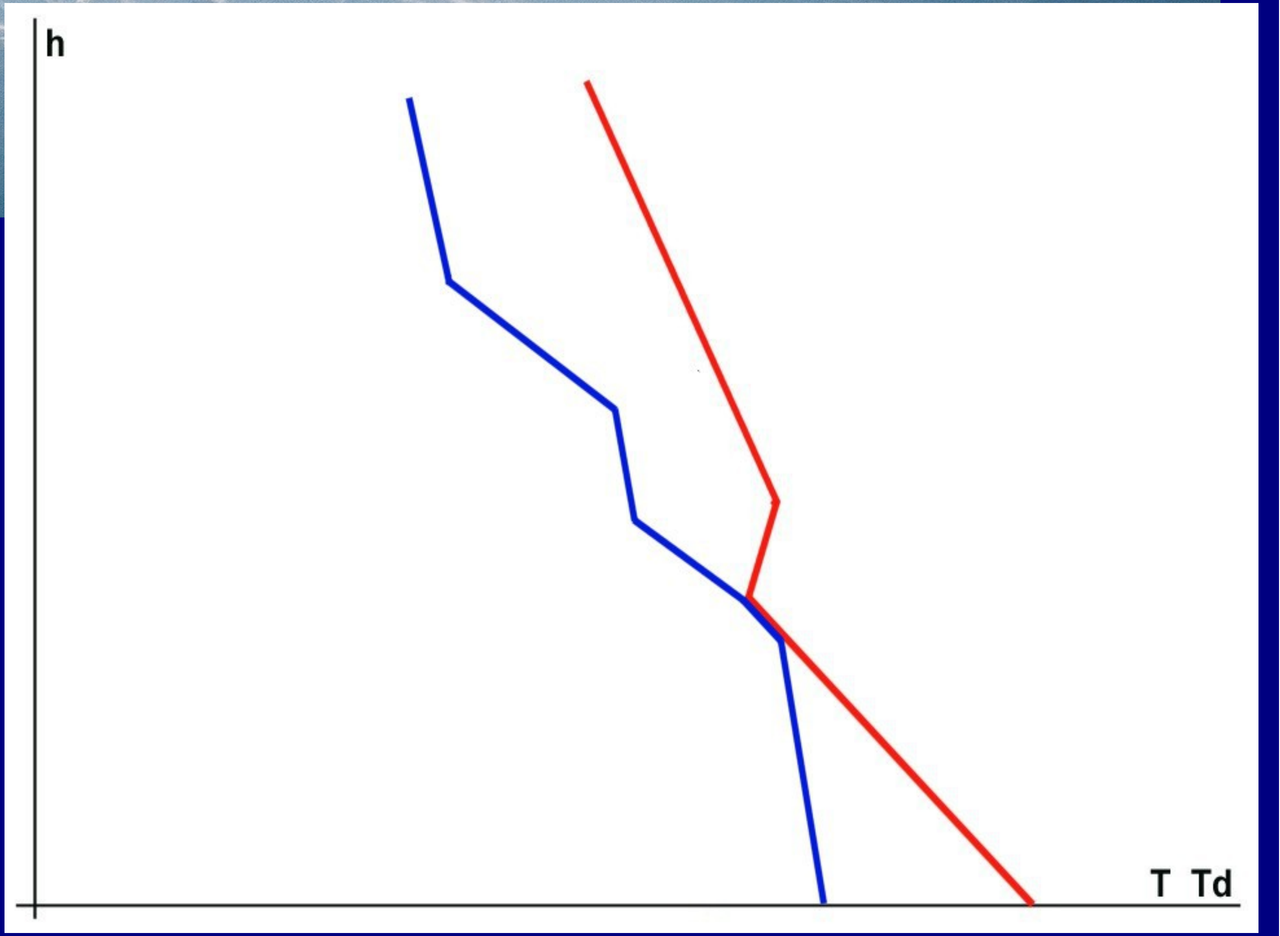


Second example: There is much moisture in the middle troposphere and dry air below. We will probably observe a day with many altocumulus and altostratus.

Third example: This is the ideal curves for thermal soaring flight with a small tightening of the "spread" (2-3 °C) at about 1500 m above the ground. Pretty and not too big cumulus will form at the top of thermals. Above, the "spread" should be as broad as possible to avoid parasitic cloudiness obscuring the sun.

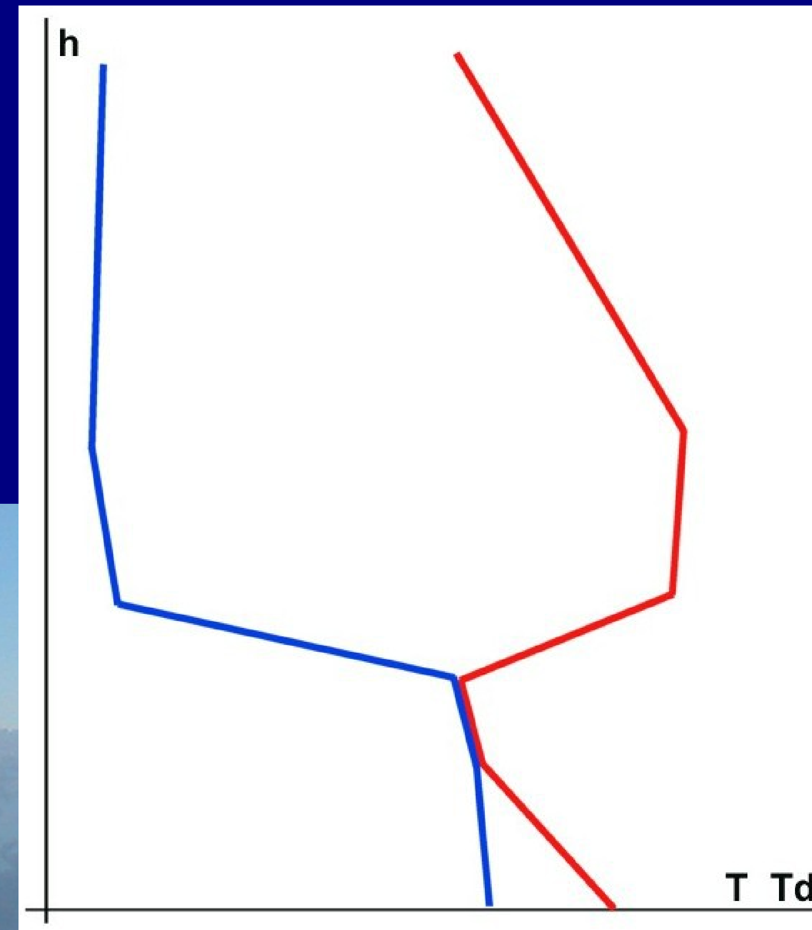


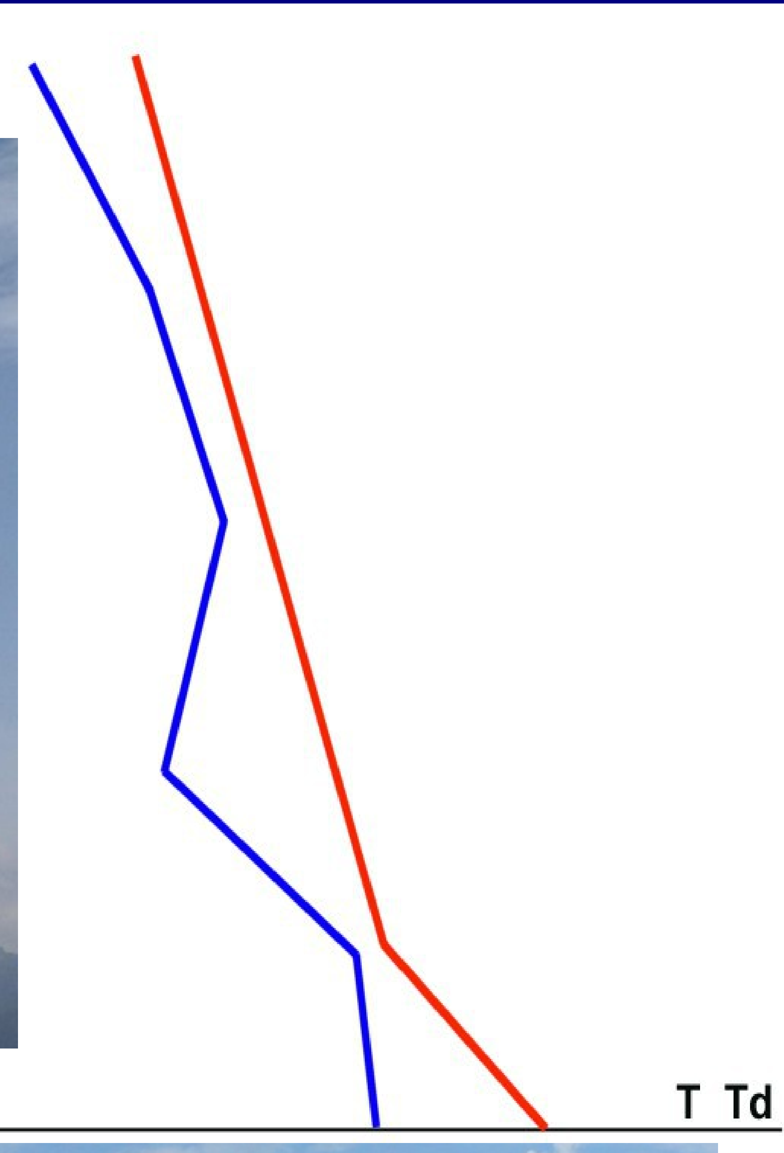




Fourth example: A zero "spread" at few hundred meters above the ground causes cumulus and stratocumulus horizontal overdevelopment.

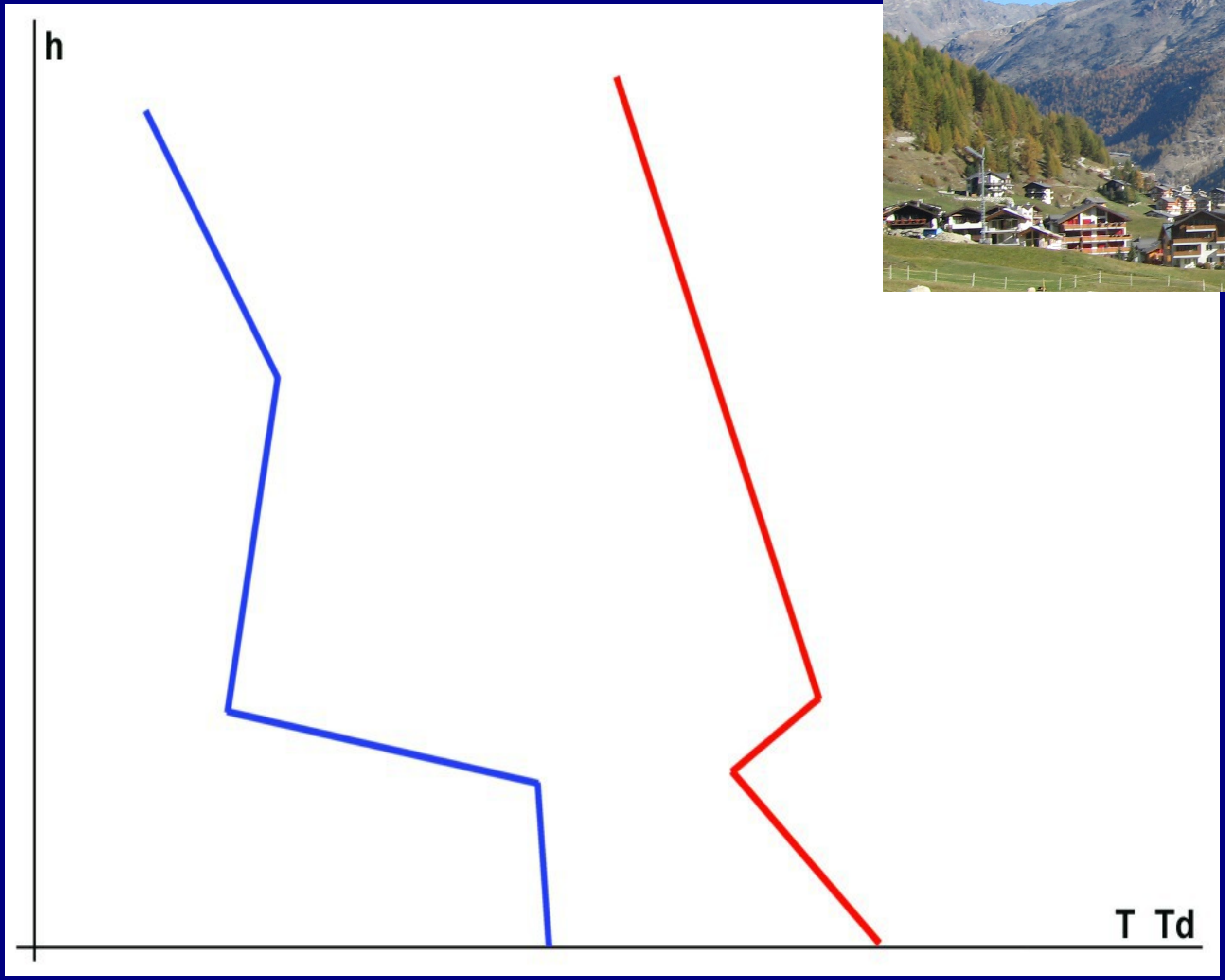
A particular variant is often encountered in late fall and winter. This is the lowland stratus during a situation of high pressure. The lower tropospheric layers are cold and wet. Above the air is hot and dry due to a global sagging (subsidence) of the air mass caused by the high pressure. The inversion above the clouds is huge.





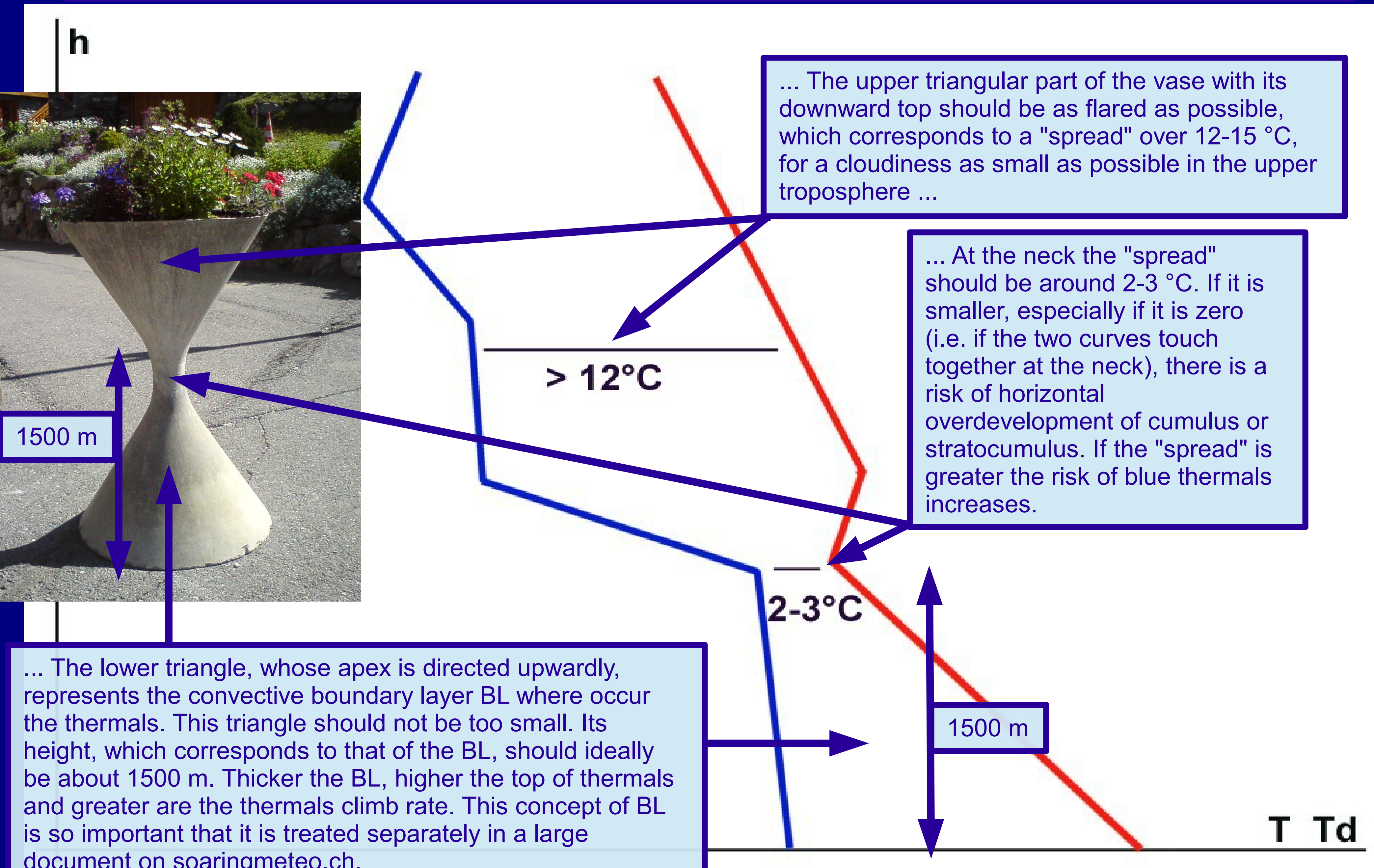
Fifth example:A overall wet atmosphere during hot summer days often leads to vertical overdevelopment of large cumulus clouds and thunderstorms. In the morning you can often recognize altocumulus or stratocumulus Castellanus in the form of a castle with its walls and towers.

Sixth example: A overall dry atmosphere leads to a very sunny and cloudless day with blue thermals.



Of course there are an infinite number of possible variations in configuration of these two curves and in tropospheric cloudiness.

Let us take now the example of our ideal curves again. The tightening of "spread" which leads to the formation of cumulus leads the two curves to draw contours of a "narrow-necked vase". Here, due to the orthogonality of the graph, the vase is inclined on the left. But there are some other features to observe ...



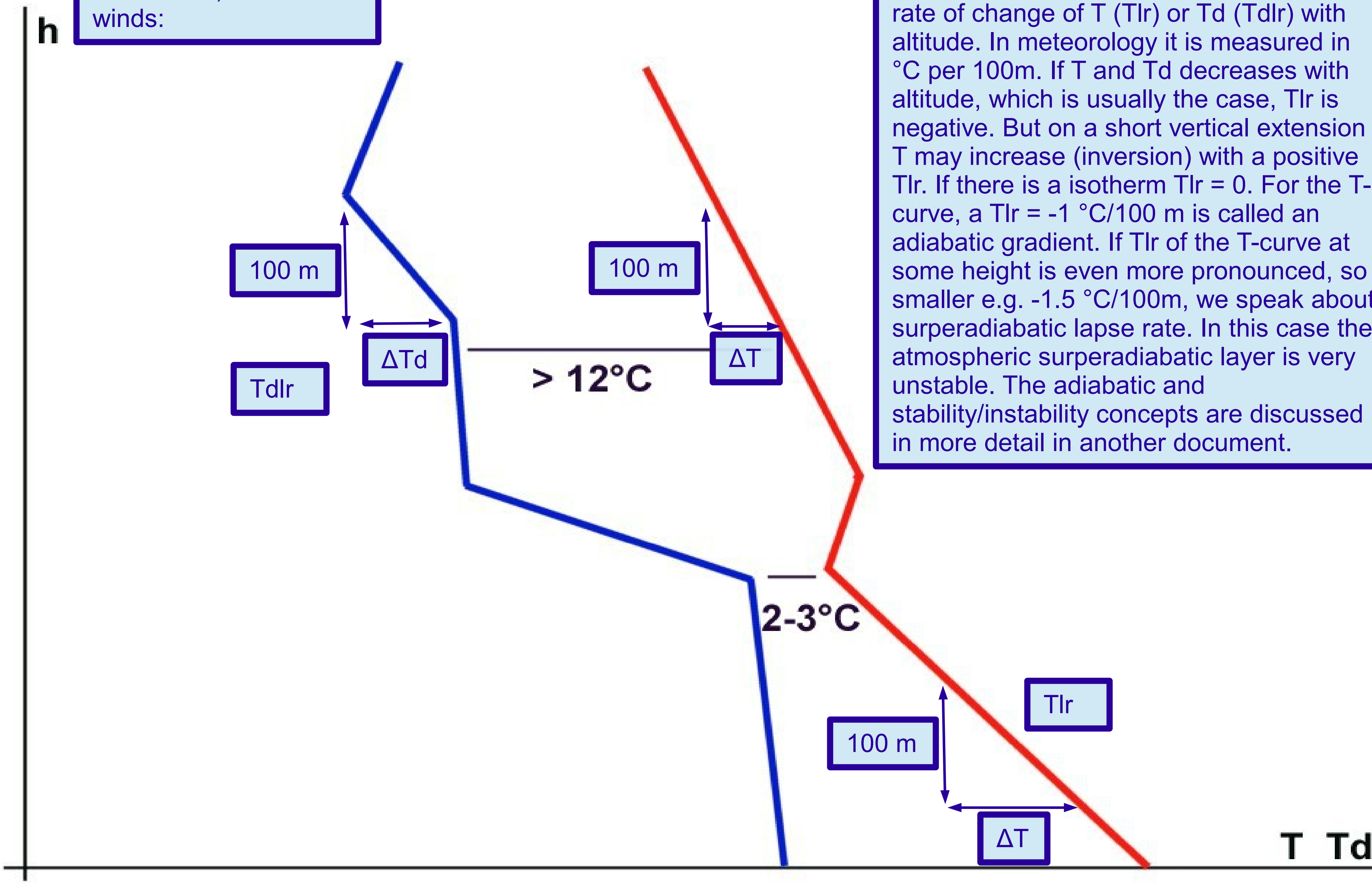
... The upper triangular part of the vase with its downward top should be as flared as possible, which corresponds to a "spread" over 12-15 °C, for a cloudiness as small as possible in the upper troposphere ...

... At the neck the "spread" should be around 2-3 °C. If it is smaller, especially if it is zero (i.e. if the two curves touch together at the neck), there is a risk of horizontal overdevelopment of cumulus or stratocumulus. If the "spread" is greater the risk of blue thermals increases.

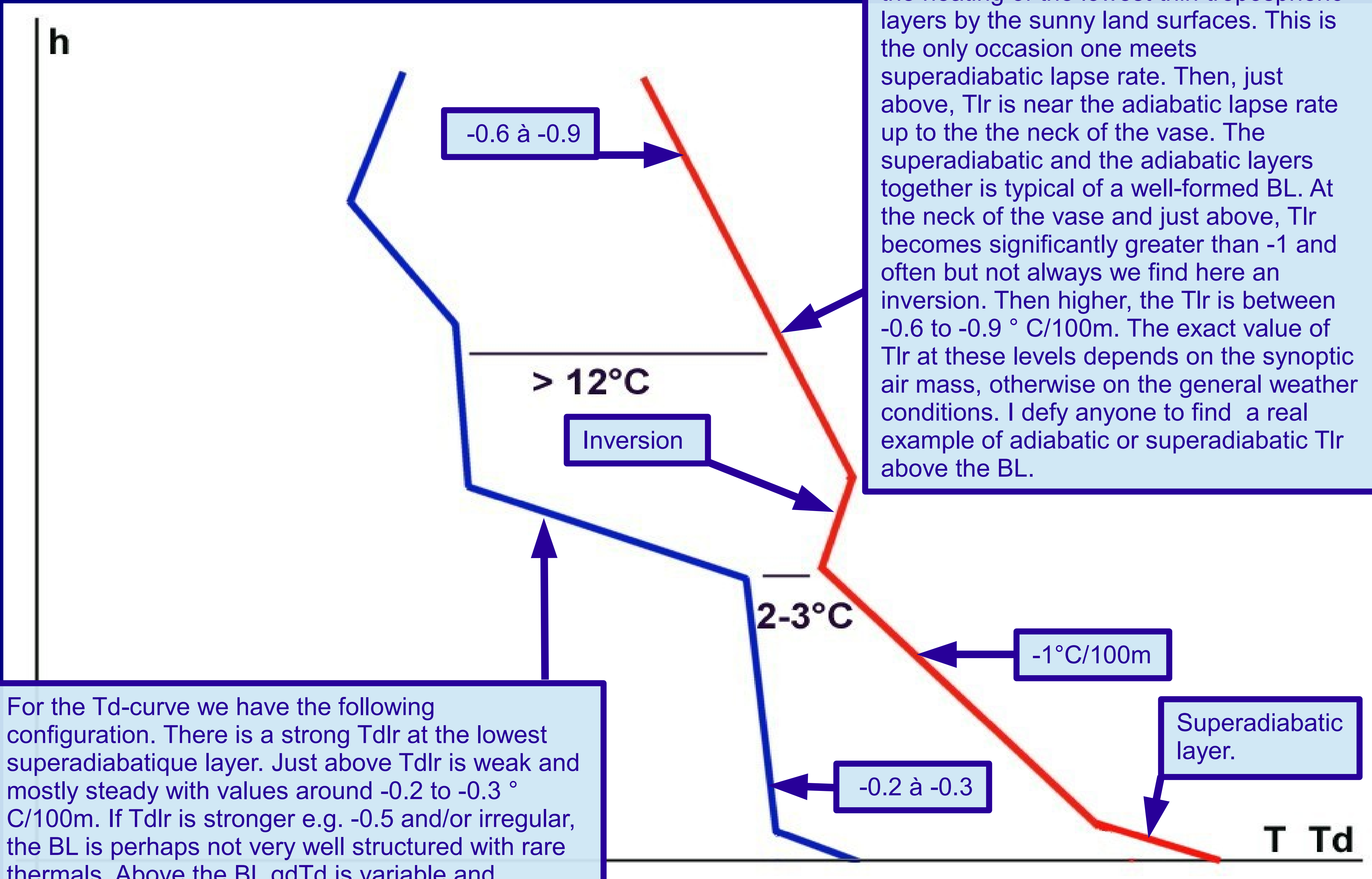
... The lower triangle, whose apex is directed upwardly, represents the convective boundary layer BL where occur the thermals. This triangle should not be too small. Its height, which corresponds to that of the BL, should ideally be about 1500 m. Thicker the BL, higher the top of thermals and greater are the thermals climb rate. This concept of BL is so important that it is treated separately in a large document on soaringmeteo.ch.

Let us examine closer, one after the other, the curves of T, Td and winds:

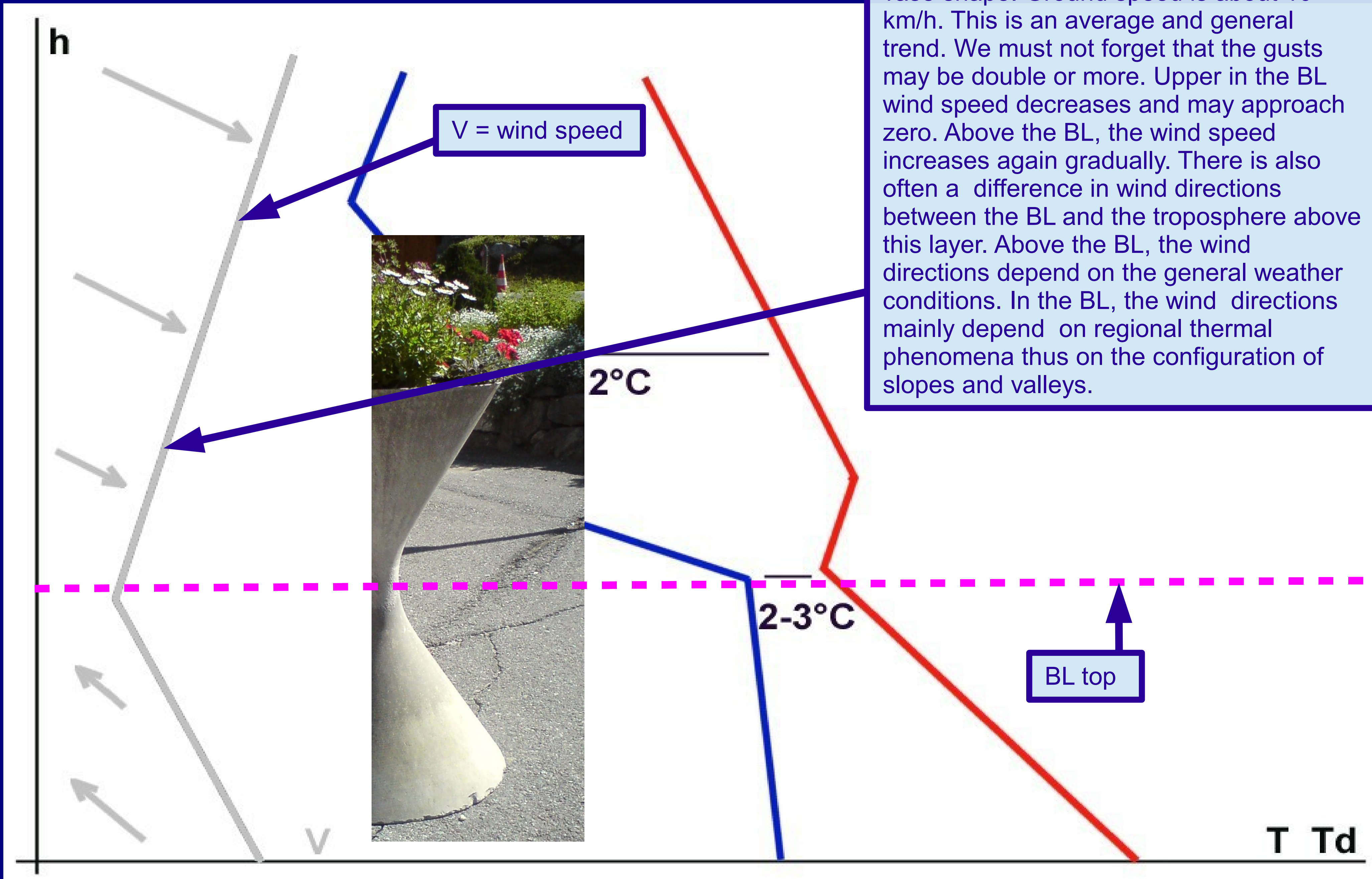
For curves T and Td, we need the concept of temperature lapse rate Tlr. This is the rate of change of T (Tlr) or Td (Tdlr) with altitude. In meteorology it is measured in °C per 100m. If T and Td decreases with altitude, which is usually the case, Tlr is negative. But on a short vertical extension T may increase (inversion) with a positive Tlr. If there is a isotherm Tlr = 0. For the T-curve, a Tlr = -1 °C/100 m is called an adiabatic gradient. If Tlr of the T-curve at some height is even more pronounced, so smaller e.g. -1.5 °C/100m, we speak about surperadiabatic lapse rate. In this case the atmospheric surperadiabatic layer is very unstable. The adiabatic and stability/instability concepts are discussed in more detail in another document.



T-curve has at the bottom, near the ground, a superadiabatic Tlr. This is due to the heating of the lowest thin tropospheric layers by the sunny land surfaces. This is the only occasion one meets superadiabatic lapse rate. Then, just above, Tlr is near the adiabatic lapse rate up to the the neck of the vase. The superadiabatic and the adiabatic layers together is typical of a well-formed BL. At the neck of the vase and just above, Tlr becomes significantly greater than -1 and often but not always we find here an inversion. Then higher, the Tlr is between -0.6 to -0.9 ° C/100m. The exact value of Tlr at these levels depends on the synoptic air mass, otherwise on the general weather conditions. I defy anyone to find a real example of adiabatic or superadiabatic Tlr above the BL.

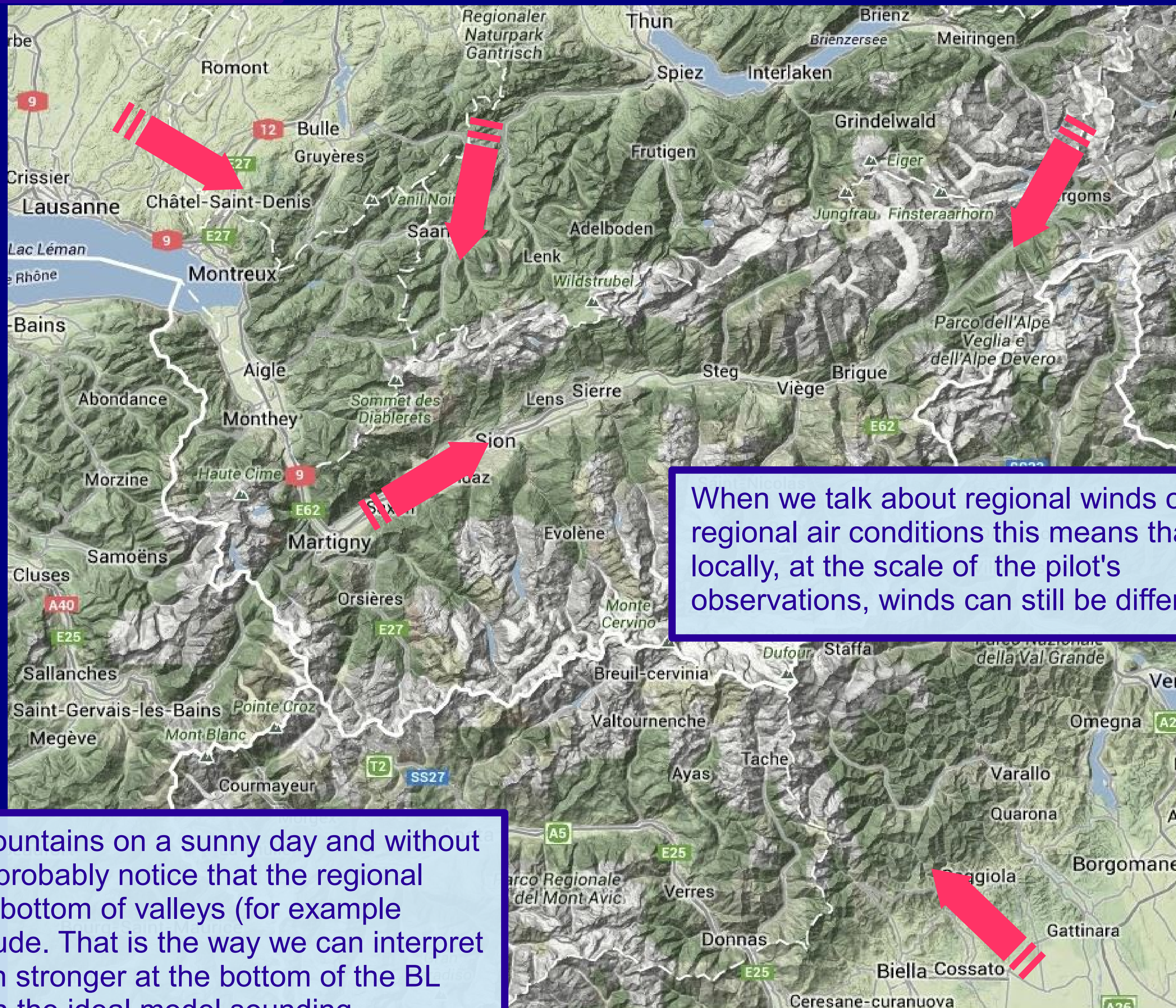


For the Td-curve we have the following configuration. There is a strong Tdlr at the lowest superadiabatique layer. Just above Tdlr is weak and mostly steady with values around -0.2 to -0.3 ° C/100m. If Tdlr is stronger e.g. -0.5 and/or irregular, the BL is perhaps not very well structured with rare thermals. Above the BL gdTd is variable and depends on the synoptic air mass.



The wind pattern is obviously very important. In the ideal case, there is a half-vase shape. Ground speed is about 10 km/h. This is an average and general trend. We must not forget that the gusts may be double or more. Upper in the BL wind speed decreases and may approach zero. Above the BL, the wind speed increases again gradually. There is also often a difference in wind directions between the BL and the troposphere above this layer. Above the BL, the wind directions depend on the general weather conditions. In the BL, the wind directions mainly depend on regional thermal phenomena thus on the configuration of slopes and valleys.

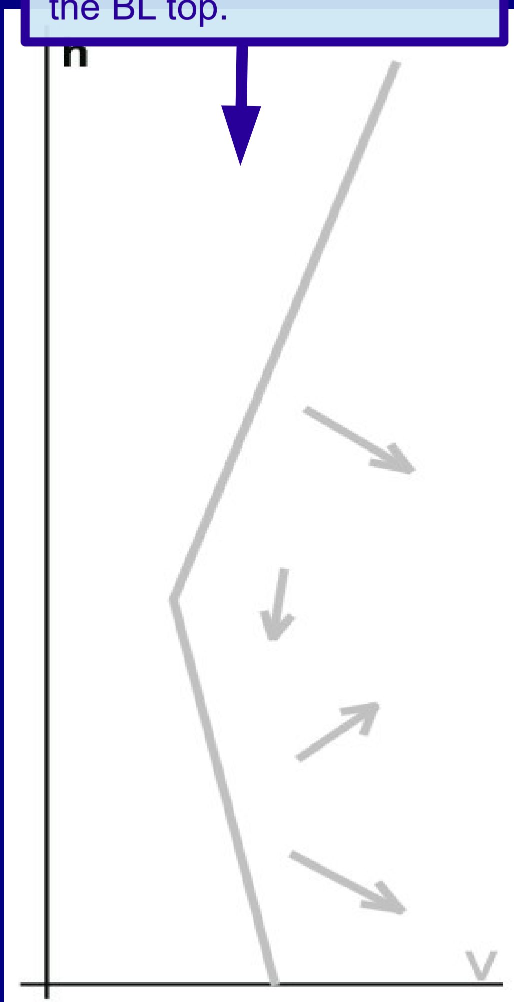
Here are examples of regional winds encountered in the BL in the center of the Alps, and typically provided by soarWRF by sunny weather and weak synoptic winds.



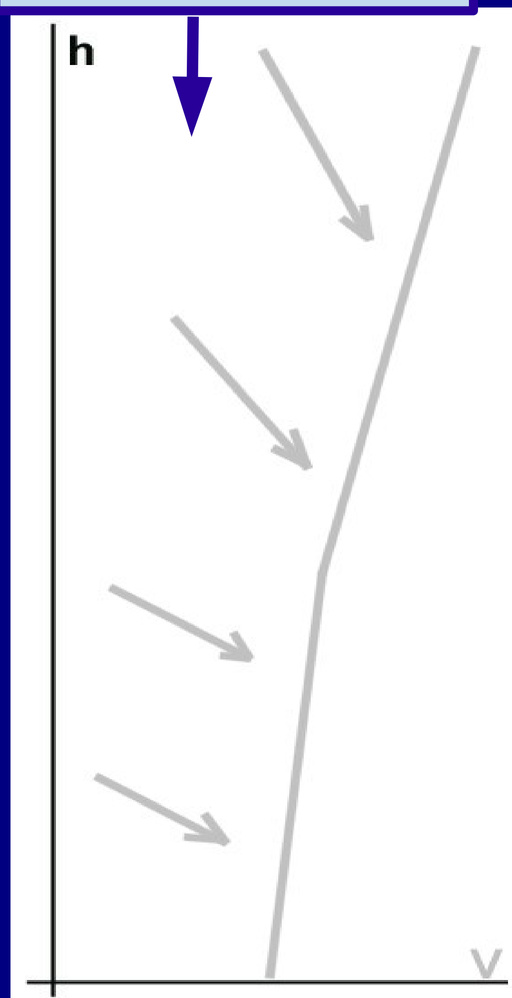
When we talk about regional winds or regional air conditions this means that locally, at the scale of the pilot's observations, winds can still be different !

If you frequently fly in the mountains on a sunny day and without a strong synoptic wind, you probably notice that the regional wind is often stronger in the bottom of valleys (for example during landings) than in altitude. That is the way we can interpret the fact that the wind is often stronger at the bottom of the BL than at its top as observed in the ideal model sounding.

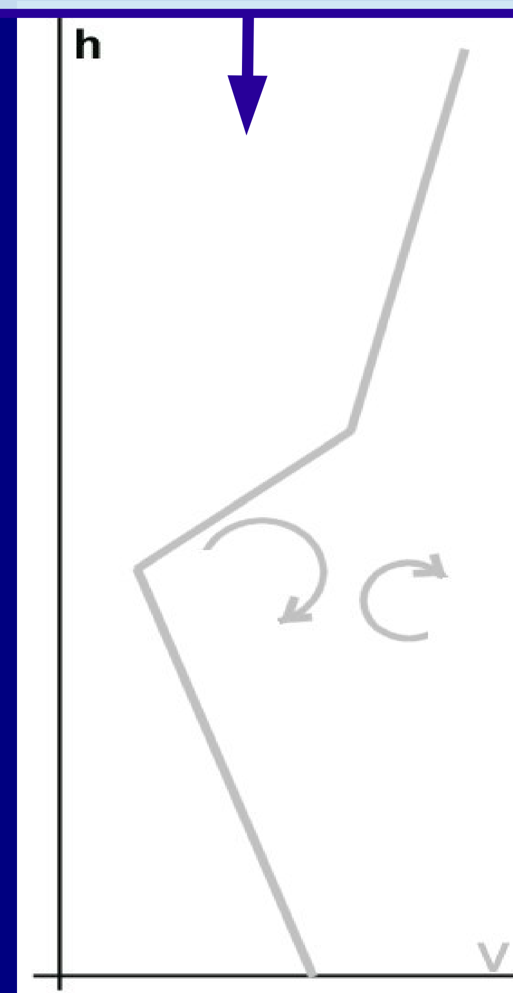
If changes in wind direction are observed in the BL from one level to the other, we can expect to encounter shear turbulences and it also means, on the other hand, that the BL is not very well structured. Otherwise said many thermals will not reach the BL top.

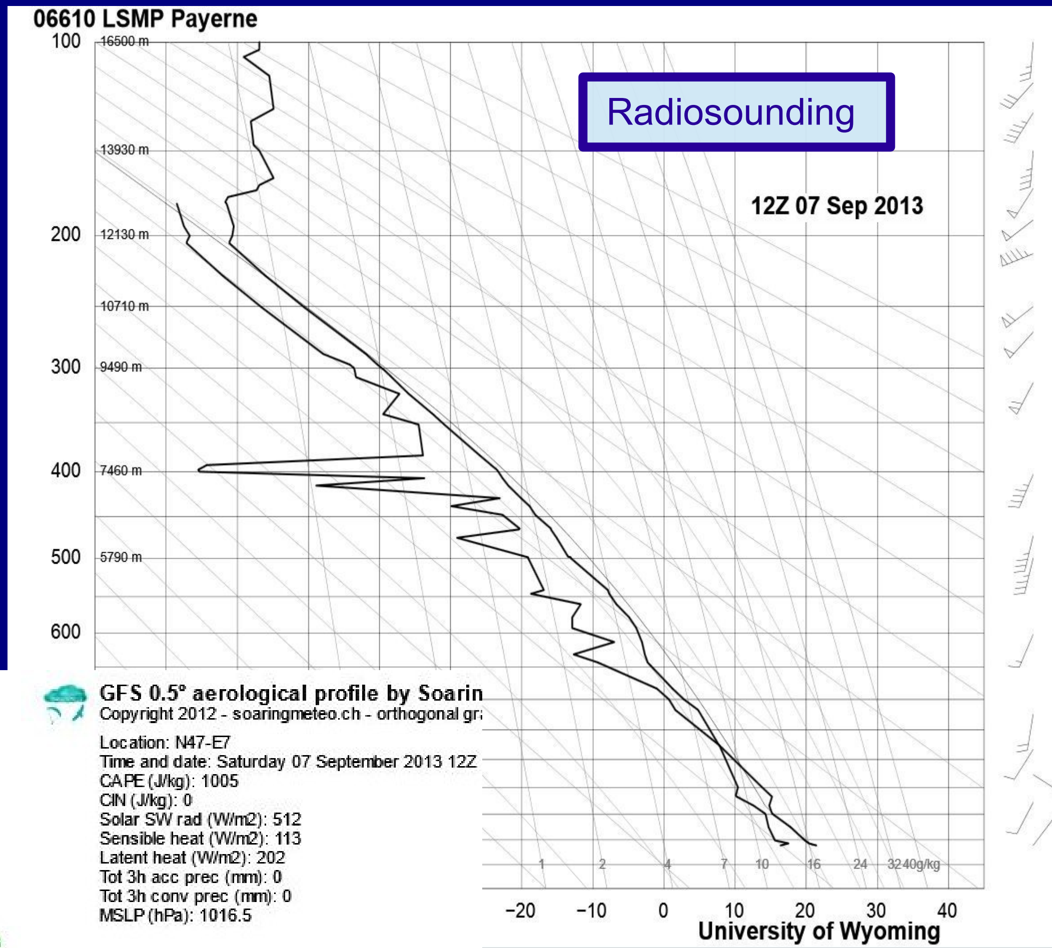


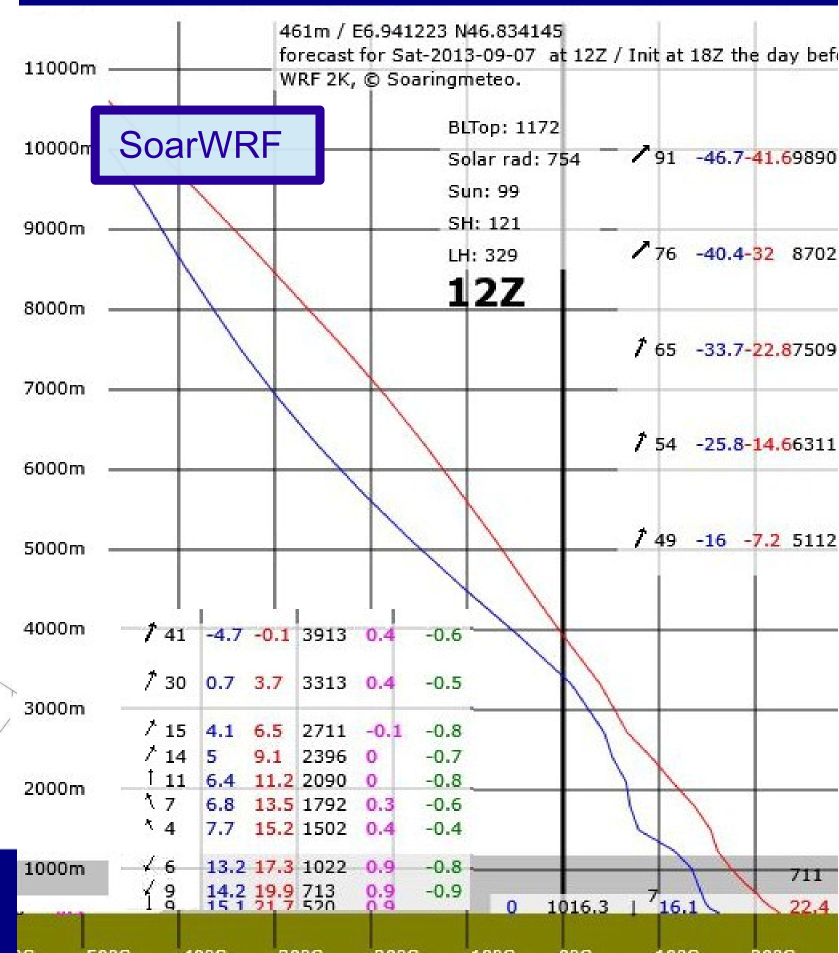
While, in the BL, the wind speed does not decrease with altitude or if the wind directions are not usual for typical regional winds, turbulences and chopped thermals should be expected because the general synoptic winds are too strong and dominant inside the BL.

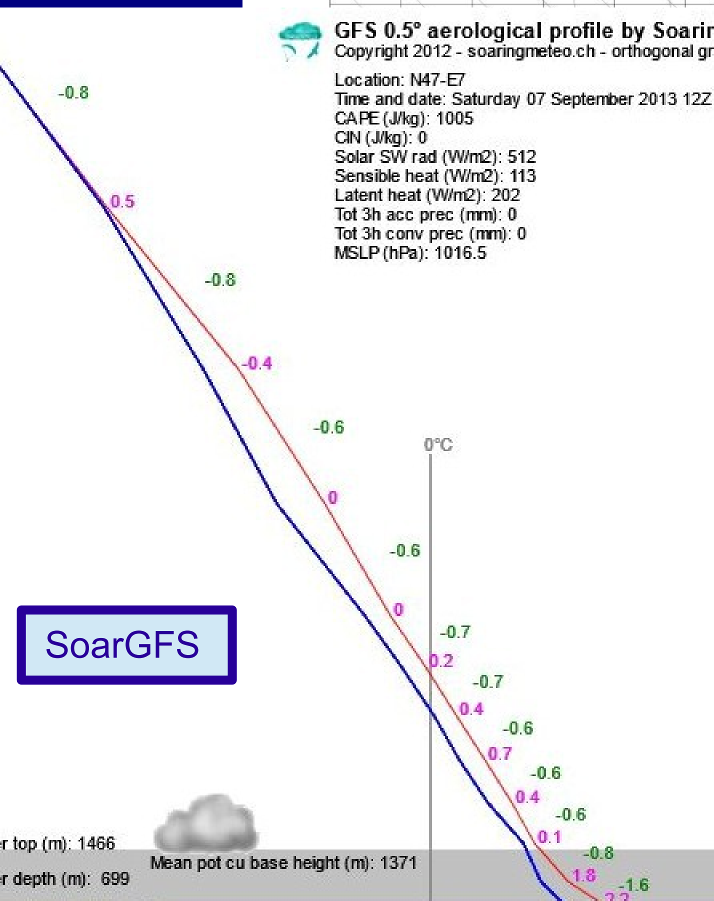


If strong winds blow just above the CC, strong turbulences should be expected at the top of the thermals. One can then observe a clear move of torn cumulus.

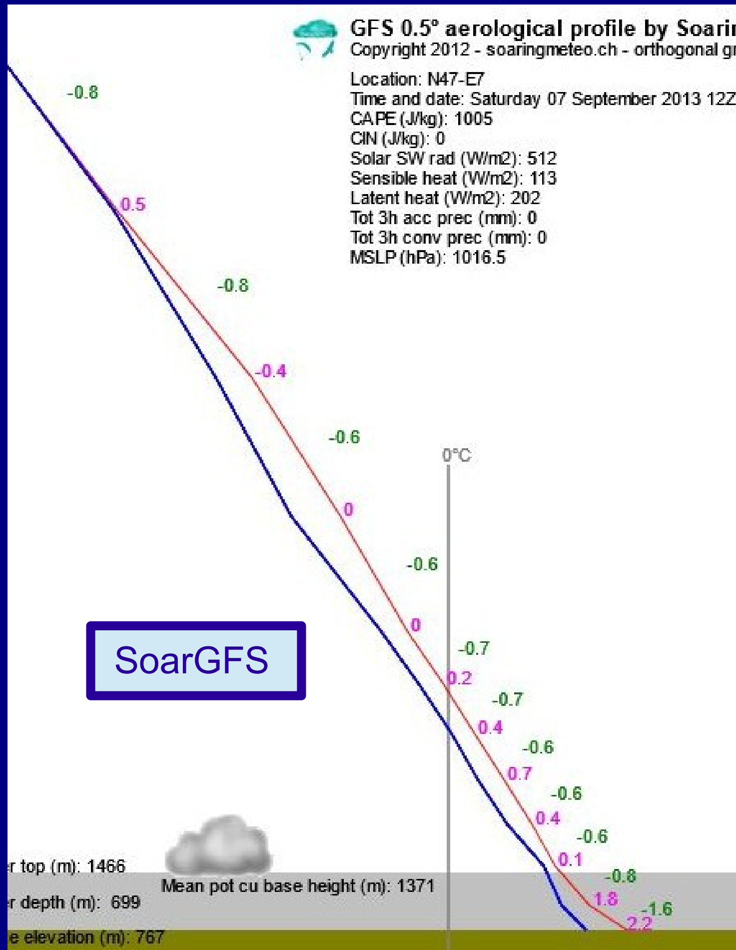


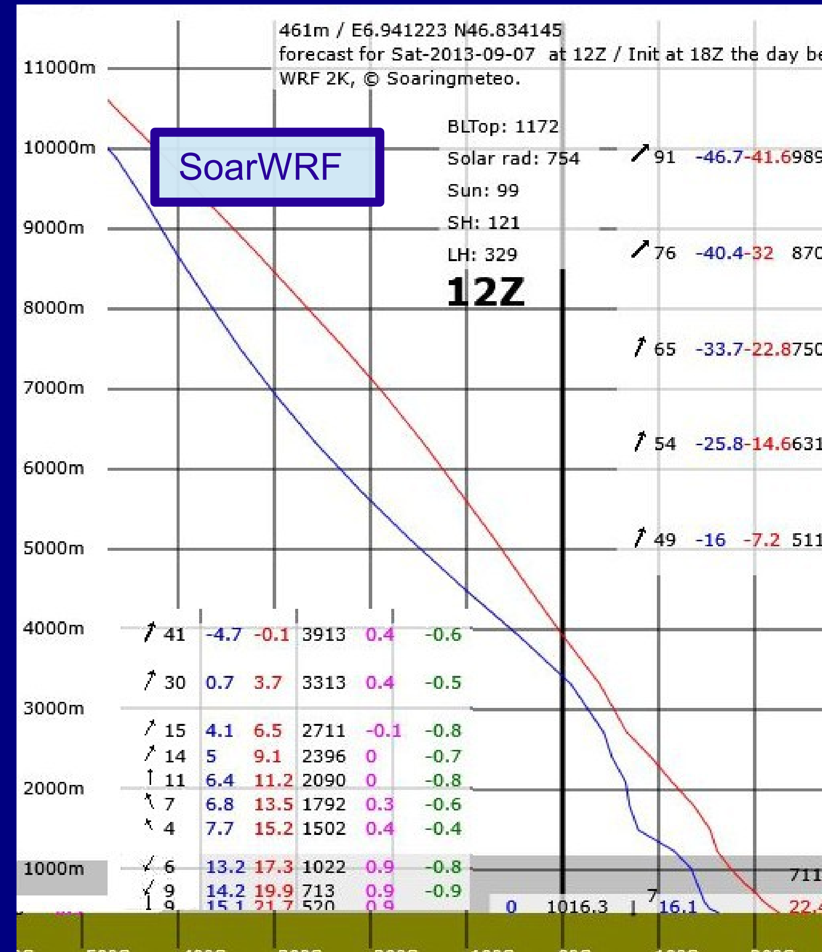






The upper air profile comes either from regular measurements at a specific place and time (i.e. radiosoundings e.g. Nimes, Payerne, Milan, Udine, München, at 00Z and 12Z) or is the result of calculations (simulation) from numerical weather models. The latter concerns us, because despite the imperfections of models, we can obtain profiles at the right time and the right place, which is not the case with radiosounding at all. SoarGFS at synoptic scale and soarWRF at regional one justly provide such predicted profiles. Measured curves from radiosounding are more jerky than those smoother provided by models. Here we compare the profiles of the radiosounding, of the soarGFS model and of the soarWRF model at the same time (September 7, 2013 at 12Z) and over about the same place (Payerne).

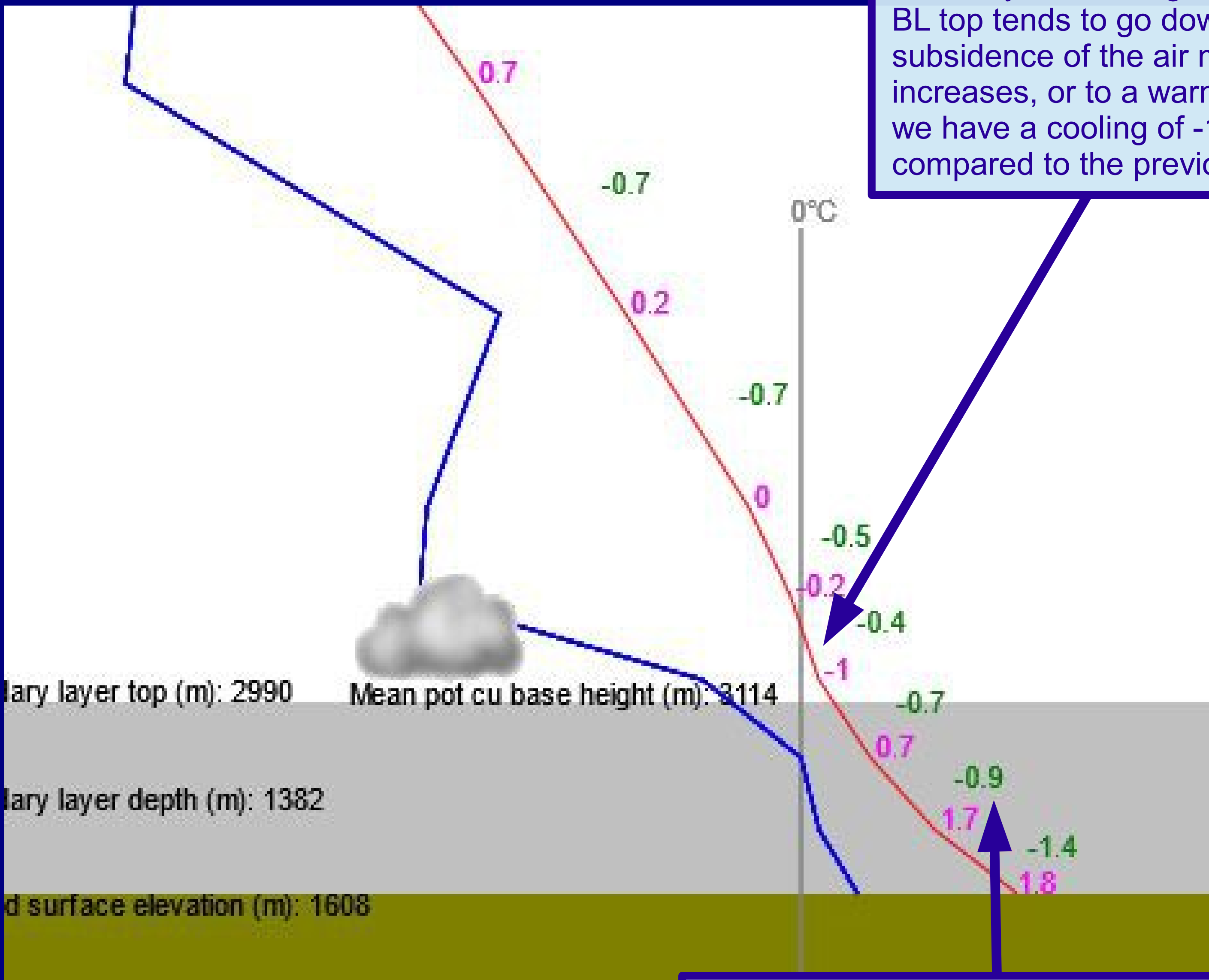




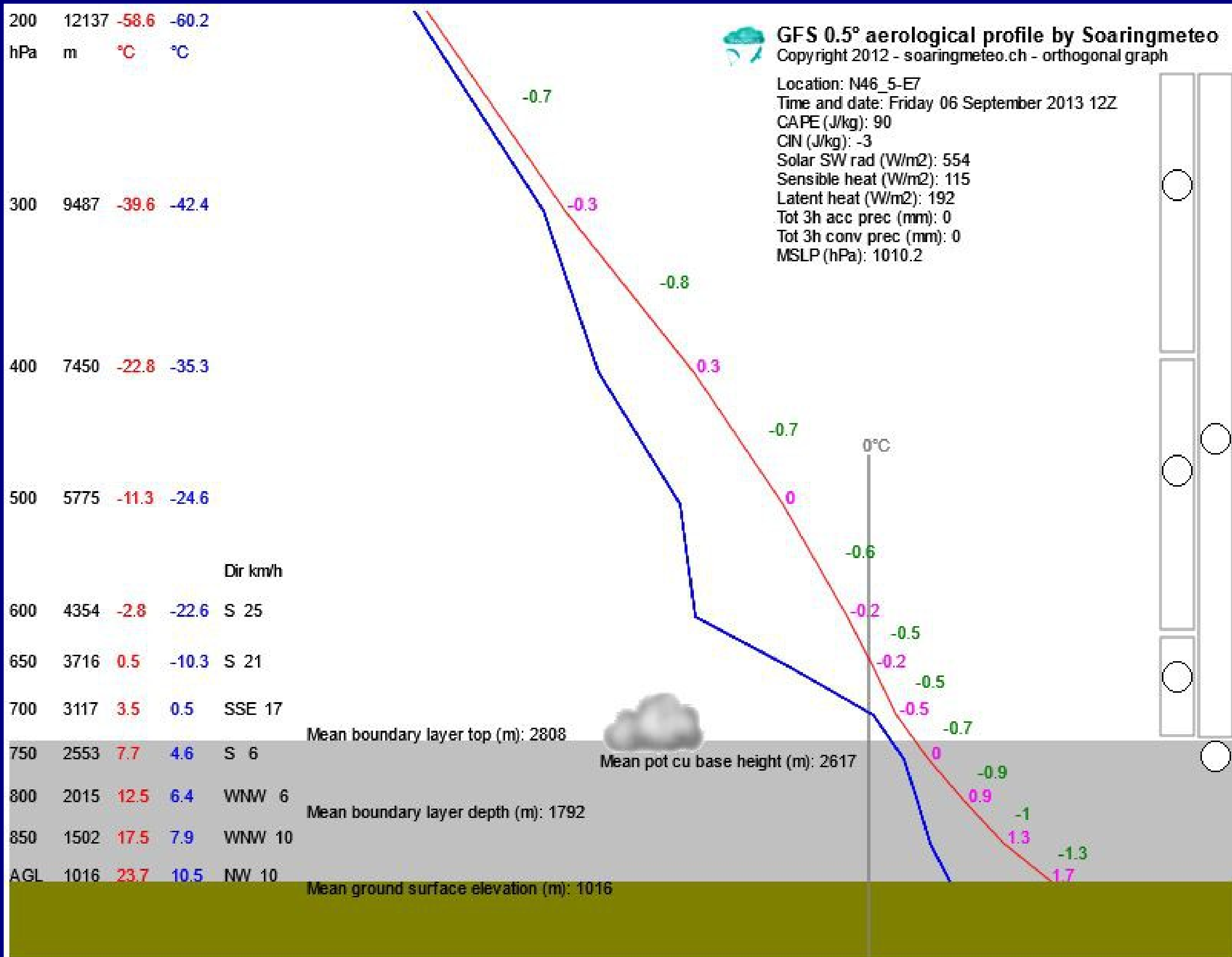
The only significant difference between soarGFS and soarWRF profiles is that the former is derived from a very smooth synoptic model, which is more difficult to interpret, and the second is derived from a regional model, closer to reality. If the GFS profile is promising in a given grid point, it does not necessarily mean that the thermals will be usable everywhere around. For example, you can expect that in the late morning, on a partly sunny west-oriented slope, in front of a large lake basin where, consequently, the local BL is usually thin, you will not meet good thermals, even though the GFS profile is favorable. The interpretation of the models is discussed in more detail in another paper.

On Soaringmeteo profiles, there is a series of colour numbers placed along the red T-curve for soarGFS and in the table for soarWRF. Numbers in fuchsia indicate the temperature change over the previous period at different altitudes. Negative values mean that there is cooling and vice versa for positive values. The numbers in green indicate the temperature gradient in degrees per 100 m. To recall the minus sign of these numbers indicates that the temperature decreases with altitude.

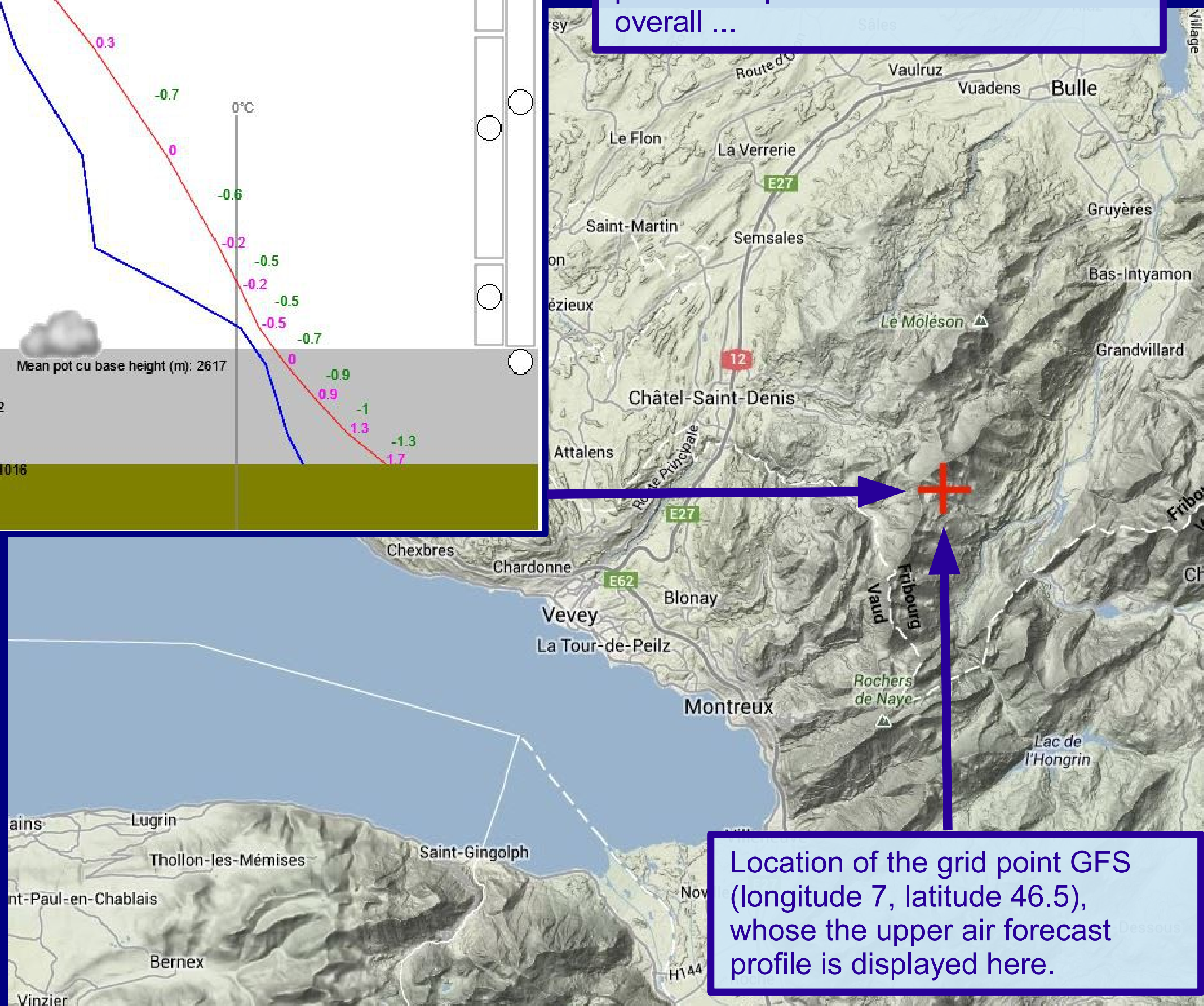
Cooling just above the BL is favorable because BL will tend to increase in height. This cooling is usually due to a general uprising of the atmosphere, when the atmospheric pressure decreases, or advection (horizontal) of cold air at this level. Inversely, a warming over the BL is unfavorable because the BL top tends to go down. In general, this is due to a global subsidence of the air mass, when the atmospheric pressure increases, or to a warm air advection at the BL top. Here we have a cooling of -1 ° C just above the BL at 12Z compared to the previous period 9Z of the same day.



The values in green (Tlr) are useful to verify that the BL is well structured with its surperadiabatic then its adiabatic lapse rates.



Here is an example, on 6 September 2013, to to understand that a favorable synoptic upper-air profile does not mean favorable everywhere. The upper-air soarGFS profile is almost perfect despite it is a little too humid overall ...



... very thick BL, light winds, wind directions typical in the BL for the region, slight cooling over the BL. This profile had already been predicted for 2-3 days before! It is supposed to represent the average conditions within a radius of several kilometers around!

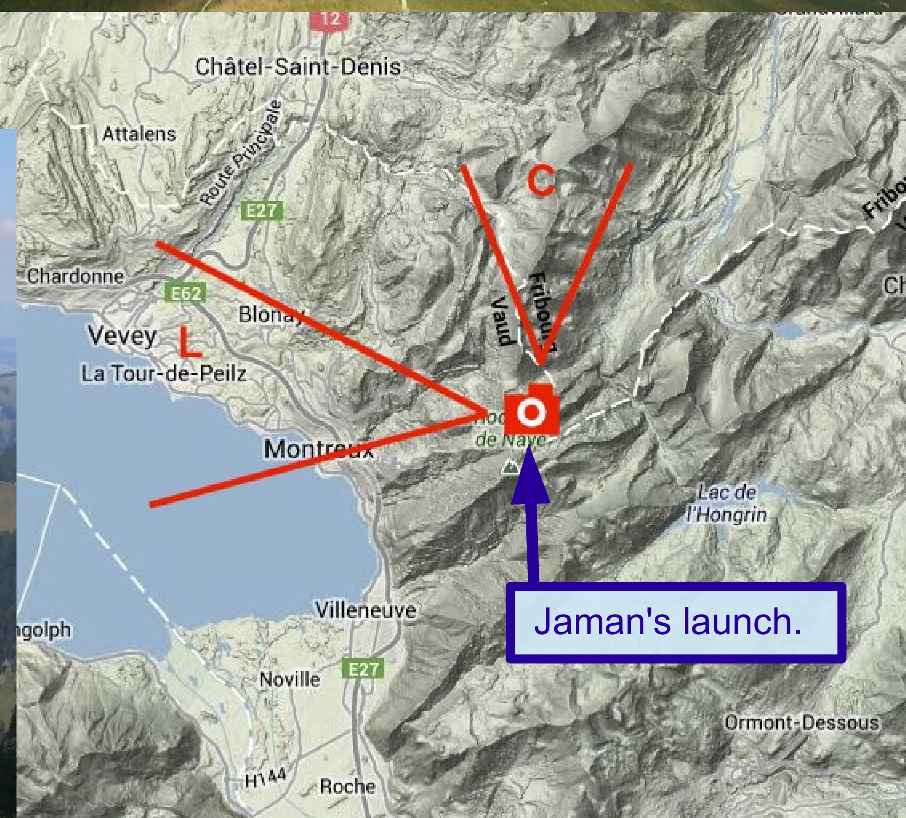
Location of the grid point GFS (longitude 7, latitude 46.5), whose the upper air forecast profile is displayed here.

The sky looks like it is to 11Z so 13h a.m. (summertime) from the launch of Jaman.

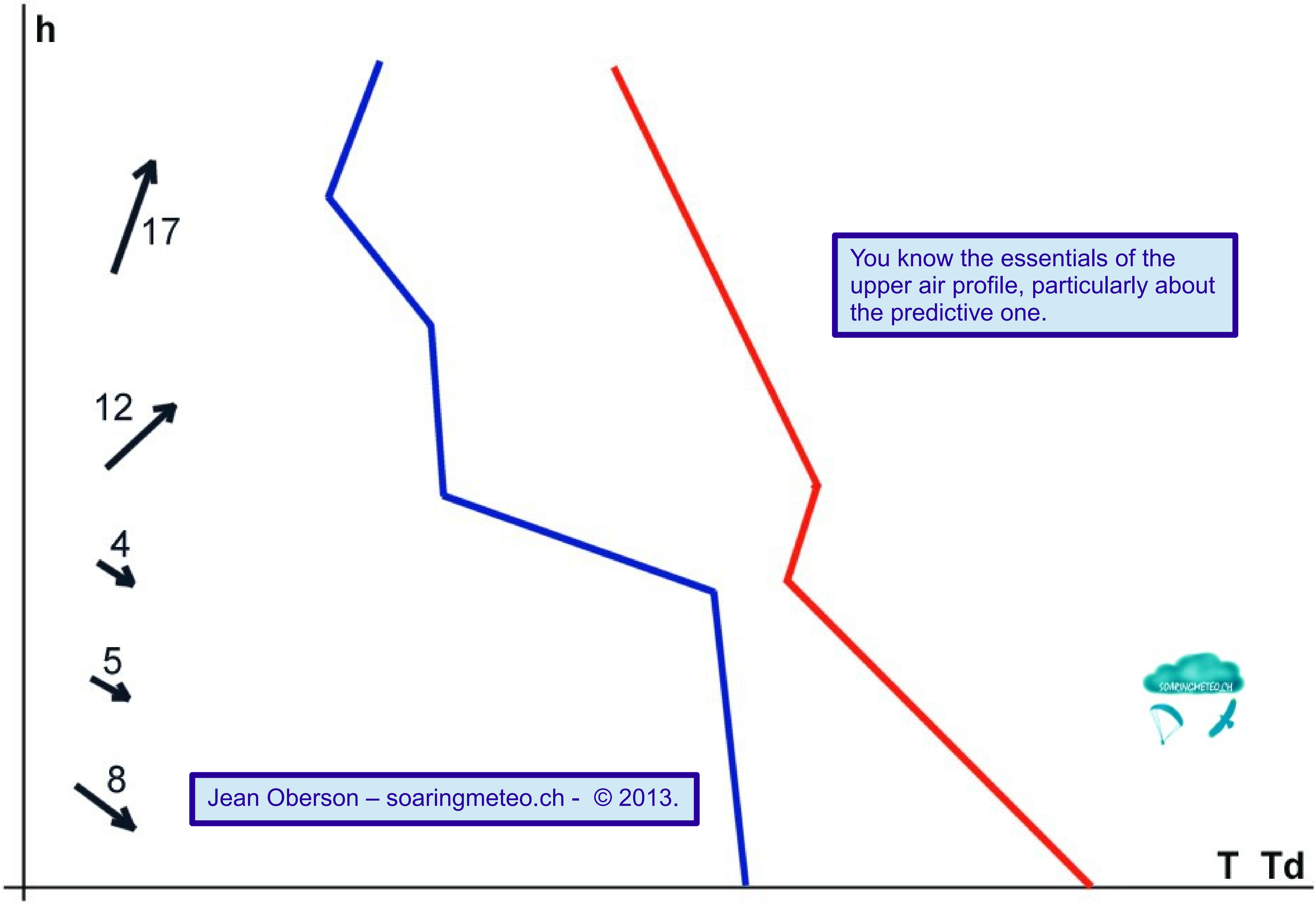
September 6, 2013

It is obvious that on the main ridge C thermal flying conditions are good, I was able to confirm it by flying. On the shores of lake basin L, there is certainly no chance to use some little thermal. The flight had to be interrupted in the middle of the afternoon because of clouds overdevelopment.

In the distance (more than 50 km) you can see the cumulus of the Jura Mountains.



Jaman's launch.



You know the essentials of the upper air profile, particularly about the predictive one.