WHETHER THE WEATHER

CLASS I – PREDICTING STABILITY WITH SOUNDINGS

X-Alps hero and meteorologist Honza Rejmánek explains how to interpret atmospheric soundings and what made August 13, 2003 a day to remember in the Alps

Alain Finet top lands Mont Blanc, August 13, 2003. Already on the summit are fellow pilots Yvan Boullen, Jean-Paul Bonfanti, Pierre Denambride and photographer David Castartelli

The European summer of 2003 is one that will never be forgotten. The mid season months of June, July and August produced week after week of hot, dry weather and booming flying conditions that saw records broken throughout the Alps. By the second week of August atmospheric conditions had reached an all-time high in terms of free flying perfection and cloudbase was topping 5,000 metres! 1,000 metres higher than a normal 'epic day'!

It was inevitable, really, that in an area as densely populated with experienced pilots as the northern Alps someone would take up the obvious challenge. On August 13, seven pilots took off from three different sites in the area and flew up and top landed on the highest mountain in Western Europe, Mont Blanc.

The feat has never been repeated and it may be a while longer until it is. But what made this day unique? Could you spot the next one coming? The ability to interpret a Skew-T diagram (a graph showing atmospheric soundings) will help you predict the conditions ahead. But before we tackle a Skew-T diagram, we need to understand stability and the make-up of the lower atmosphere, where we fly.

BOUYANCY, STABILITY AND LAYERS OF AIR

The first 100 metres of the atmosphere is called the surface layer. This is where the heat of the earth's surface, resulting from the sun, is exchanged with the air. This layer is the birthplace of thermals.

If a parcel of air, or thermal, is less dense than its surroundings, then it is buoyant and will rise. There are two ways to make a parcel of air more buoyant: make it warmer and/or make it lighter by adding a lighter gas such as water vapour. As long as the parcel of air remains warmer than its surroundings it'll continue to rise. How quickly and how high a thermal rises depends largely on how well it maintains the buoyancy it gained in the surface layer and the temperature of the air it is climbing through.

The air above the surface layer is called the mixed layer. It extends from the surface layer to cloudbase, or if no clouds are present, to a stable layer that stops thermals' ascent. The temperature difference between the air inside and outside a thermal as it ascends through the mixed layer is very small, less then 2°C, which is why in my fourteen years of flying I've never felt a noticeable temperature change as I enter a thermal.

If the thermal enters air whose temperature is decreasing less than the thermal is cooling due to expansion, then the air is considered stable. The thermal will eventually come to a halt as the air around it is no longer cooler and the thermal's buoyancy has been neutralised. The level it stops ascending at is called the equilibrium level, although momentum will actually cause some overshooting of this equilibrium. With these concepts understood we can begin to tackle reading a sounding.

THE SKEW-T LOG-P DIAGRAM

Two of the main thermodynamic diagrams used to interpret stability are the Skew-T (used in the US and generally adopted elsewhere) and the Tephigram (used primarily in the UK and Canada). Both offer similar information - temperature and humidity against altitude - and from that we are able to plot the lapse rate and get a real-time picture of the air above us. The information is gathered by a disposable instrument called a radiosonde that is sent up in to the atmosphere on a balloon and then transmits back to a recording unit on the ground.

Learning to read a sounding on a Skew T is important since it can help us see what the day's soaring conditions might be like. At first glance the diagram looks overwhelmingly complex, but broken down into bite-size pieces all those crazy lines start to make sense and it's not so bad.

LAPSE RATES

To understand a Skew-T diagram you need to understand lapse rates. Lapse rates are how we express the stability of the air through the rate air is cooling. There are three different types of lapse rate, which need to be differentiated from each other before we go any further: one measures the rate the actual air mass is cooling with altitude, while the other two express the rate a parcel of air, or thermal, will cool as it rises up through the air mass. The reason there are two different lapse rates for measuring the cooling of rising air is that there is one for dry air and one for wet air.

ELR - ENVIRONMENTAL LAPSE RATE

This is the all important one. It's a plot of the actual temperature at different altitudes at a certain time and place. It's obtained by the weather balloon and radiosonde. The instruments transmit their measurements back to earth from different pre-set altitudes and we are able to build a picture of what the air above us is like at that moment. The ELR is the right-hand plotted line on a Skew-T.

THE DRY AND SATURATED ADIABATIC LAPSE RATES

DALR – Dry Adiabatic Lapse Rate

This represents the rate that dry, uncondensed air cools as it rises. Essentially, it's the rate a thermal cools as it rises. It's the lapse rate against which we judge the ELR, to work out if the air mass is stable or not and whether we will have a good soaring day. It's important to remember that the DALR is not a measurement taken from the air itself, rather it is a formula, and as such never varies. Air, without condensed water, cools at approx 10°C per 1,000 m, or 1°C per 100 m as it rises. The DALR is marked on the Skew-P as a series of parallel green lines.

SALR - Saturated Adiabatic Lapse Rate

Water takes lots of energy to evaporate. It is released upon condensation. So, once the water in the air condenses and forms cloud, the rising cloud cools more slowly than a thermal. The rate of cooling of condensed air can vary depending on the actual amount of water present. Unlike the DALR, the SALR isn't constant, it is dependent on the dew-point temperature, measured by the same weather balloon that records the ELR, and can range from 4°C per 1,000m to over 9°C.

Once we reach an altitude where water vapour is condensing and cloud is forming we stop comparing the ELR against the DALR to

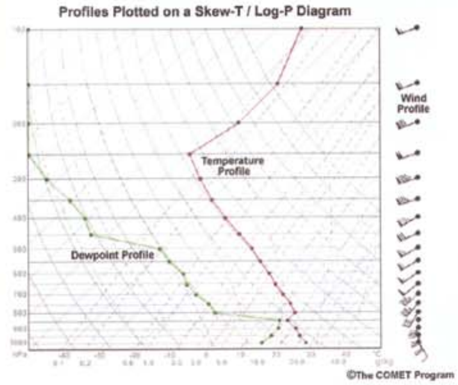

Figure 2.

judge stability and switch to the SALR. This is an important figure in working out how convection will behave above cloudbase and whether we will have overdevelopment or not.

The important point to understand here is that it's the ELR that tells us the rate the air is actually cooling at certain altitudes on a given day. The adiabatic lapse rates DALR and SALR just tell us the rate rising air cools in a thermal or in a cloud.

THE PLOTTED PROFILES

The most noticeable items on a Skew-T diagram are the two plotted lines that rise upwards. The right-hand one is the ELR, indicating the temperature profile of the atmosphere, the left-hand one is known as the dew-point profile and is an indicator of the moisture content of the air.

The closer together the two lines are, the moister the air is and the easier it is for it to form cloud. The further apart they are the drier the air is.

Behind the ELR and the dew-point profile is a series of coloured lines.

ISOBAR LINES

The horizontal lines represent atmospheric pressure and therefore height. Globally averaged sea level pressure is 1,013 hectopascals (hPa) or millibars (mb). In the first 3,000 m it's safe to assume that each 100 mb of pressure decrease is equivalent to approximately 1,000 m of altitude increase. So when we look at a Skew-T we can assume that the horizontal line at 1,000 mb is approx. 130 m above sea level. From there we can estimate that the next line at 900 mb is approx. 1,130 m ASL and the line at 800 mb around 2,130 m. Using this as a guideline we can see which part of the chart refers to which altitudes.

The spacing of the lines increases with altitude as the weight of the atmosphere decreases and there

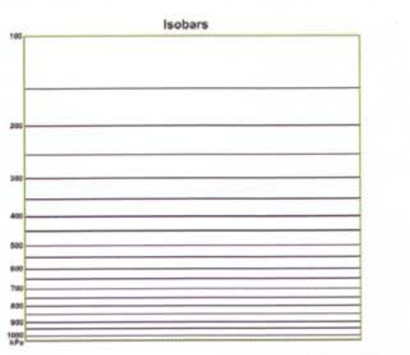

Figure 3. Isobars, lines of equal pressure. Each 100hPa represents approximately 1000m of altitude in the bottom 3000m of the atmosphere

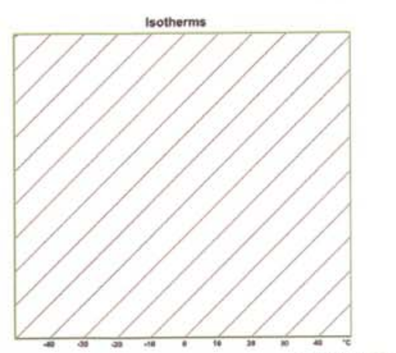

Figure 4. Isotherms, lines of equal temperature.

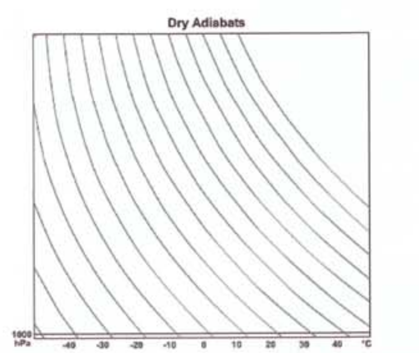

Figure 5. Dry Adiabats, the rate at which dry air cools as it ascends. When the ELR is the same as the DALR then it parallels a dry adiabat on a Skew-T

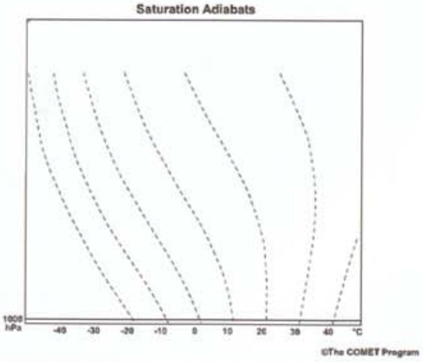

Figure 6. Saturation Adiabats, the rate at which saturated air cools as it ascends

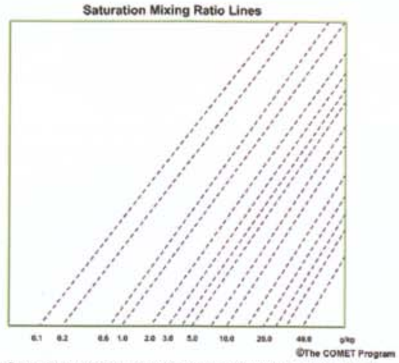

Figure 7. Saturation mixing ratio lines represent the maximum of water vapor in grams that can exist in a kilogram of air before condensation begins

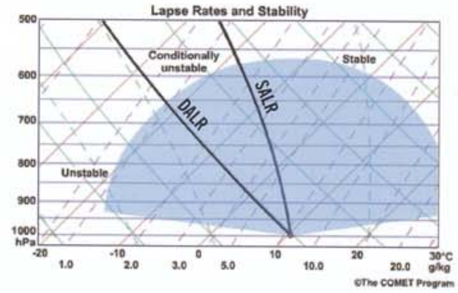

Figure 8. Different stability scenarios

is less compression. When we get to roughly 5,500 m we reach 500 mb and approximately half of the atmosphere is above us and half is below. As free flying pilots we are mainly interested in the bottom quarter of the diagram, as that is the altitudes we fly in.

ISOTHERM LINES

Next come isotherms, tilted blue lines that ascend from left to right representing areas of equal temperature within the atmosphere. If the ELR runs parallel to an isotherm line it means that temperature is not decreasing with height and the air is totally stable and almost inert.

Lines are drawn in 10°C increments, which are labeled at the bottom of the diagram.

DRY ADIABAT LINES

These solid green lines rise in a leftward curve and express the DALR, the rate at which dry air cools as it ascends. Plotting the ELR against these allows us to judge the stability of a day at a glance.

SATURATION ADIABAT LINES

These dashed green lines represent the SALR, the rate at which saturated air cools as it ascends. Unlike the dry adiabat lines, they're not uniformly angled because SALR has several variables (such as the original water content of that parcel of air) so will change with different dew-point temperatures.

SATURATION MIXING RATIO LINES

Finally we have the saturation mixing ratio lines, dashed purple lines running from the bottom upwards and rightwards. They represent the maximum amount of water vapour in grams per kilogram of dry air before saturation is reached. In other words, they show how much water vapour the air can 'hold' at different temperatures and pressures. These lines can be used to estimate cloudbase, which we will discuss next issue.

READING A SOUNDING

The single most important thing for us amid the mind-boggling confusion of lines is the right-hand solid plotted line, the ELR. Both the angle of the ELR and its position relative to the DALR and SALR tells us many things about the air. It, and the changes in angle, represent air with different characteristics and hence changes in stability.

The blue semi-circle in fig 8 represents some of the positions the ELR can be in. One of the lines that represents the DALR, normally a thin solid green line, has been thickened to emphasise its angle and position, as has one of the SALR lines, normally a dashed green line. By judging the ELR against the two lines we can work out the stability of the air.

If the ELR is parallel to the DALR below the condensation point, it tells us the air is well mixed and thermals will climb easily through it. Essentially, we'll have fantastic soaring conditions. In meteorological terms this is called 'dry neutral'. Any buoyancy gained in the unstable surface layer gives the thermal a free ride through this neutral layer.

If the ELR is in-between the DALR and the SALR then we have 'conditionally unstable' air. If the ELR is conditionally unstable to a great height, perhaps from 2,000 m -10,000 m, then it tells us that air parcels will be able to rise to 10,000 m. If the condensation point is only at 3,000 m we can quickly see that the clouds could potentially be 7,000 metres tall and consequently there is a very strong chance of overdevelopment. Pilots often call this scenario 'unstable'. In reality, in meteorological terms, it is 'conditionally unstable'.

A better situation for the soaring pilot is to see the ELR indicating neutral air up to the dew-point, then a change in the air towards greater stability so as to cap the height of convection and possible cloud development.

If the ELR is sloping the other way, towards the right, and into the stable area in fig 8, we have stable air that thermals won't travel through particularly well, if at all.

An airmass can change its characteristics through the altitudes, incorporating every degree of stability and instability; the ELR reflects this.

JUDGING STABILITY FROM THE ANGLE OF THE ELR

Figure 9 shows some of the many different angles the ELR may be at and what each angle means. Essentially, the further left the line leans the more unstable the air is and the better the convection will be; the further to the right it leans the more stable it is and the worse the convention will be, if there's any at all!

- A - Autoconvective, very unstable
- B - Unstable
- C - Dry neutral – note how the ELR follows the DALR
- D - Conditionally unstable
- E - Moist neutral – note how the ELR follows the SALR
- F - Stable
- G - Isothermal, very stable – note how the ELR follows the isothermal line indicting that the air remains at the same temperature even as it gets higher.
- H - Temperature inversion, extremely stable – indicating you should stay at home and have a barbecue

THAT SPECIAL DAY

Although we have no soundings for Mont Blanc for August 13, 2003 we can review the Skew-T diagrams from the nearby city of Lyon. Lyon is situated 150 km from the summit of Mt Blanc in the plains, so certain aspects of the readings will be different, but we can still consider them to be in the same air mass. The soundings are for 00:00 (fig 10) and 12:00 (fig 11) on the day Mont Blanc was top landed. If we study the Skew-T we can see the ELR fitting just about each of the scenarios A – H described in fig 9.

At 00:00 we can see a ground level inversion, (H), the result of the heavy, cold air of the night descending and then being further cooled by the ground. Essentially, the air closest to the ground is colder than the air only a couple of hundred metres higher.

Switching then to 12:00 we see the situation has reversed and the warmest air is now closest to the ground, a result of the sun's heating of the ground, and is forming an unstable surface layer, (A,B), this is where thermals form. Above the surface layer is the mixed layer, also referred to as the convective boundary layer, which is the area we fly in.

On both the Skew-T diagrams the ELR parallels DALR, or the dry adiabats, until 650 – 600 mb. This is considered to be 'dry neutral' (C) and means that a thermal will retain the positive buoyancy it acquired in the surface layer and rise all the way through these altitudes.

At around 600 mb the thermal reaches a layer of more stable air, which inhibits its ascent. The change in air was visible on the Skew-T at 00:00, the night before the big flight. On the Skew-T at 12:00 it became even more visible as an inversion (H). The night before the big flight pilots would have been able to look at the 00:00 Skew-T and see that the air mass over Lyon was capable of carrying good thermals to around 4,000 metres, which was exceptionally high for the region.

The mixed layer normally extends higher over the mountains than over the adjacent flatlands. This is simply because the ground, and the surface layer which heats the air, is higher, so it forces the mixed layer higher. Clued up pilots would have been able to look at the 00:00 sounding and predict thermals in Chamonix to climb to over 5,000 metres.

In the next issue we will look at how cloudbase is predicted and how to read the wind profile from the Skew-T. This will allow us to truly appreciate why this day was so special. XC

To find the closest sounding to your flying site go to http://weather.uwyo.edu/upperair/sounding.html. Those who wish to delve deeper into the topics presented are encouraged to log onto the COMET program at www.meted.ucar.edu.

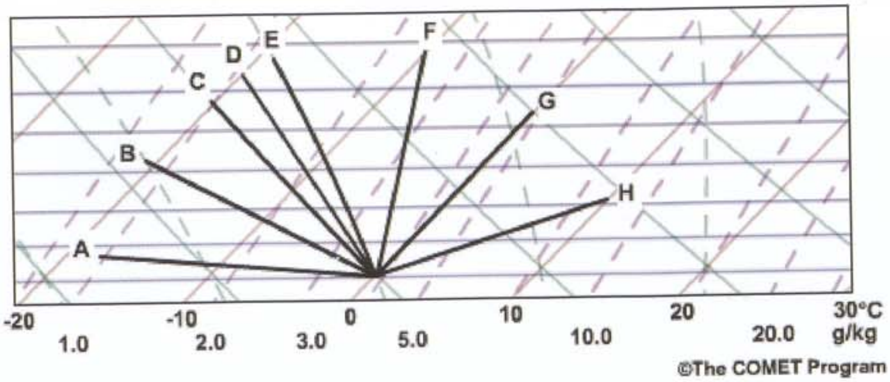

Figure 9. An array of possible slopes of the Environmental Lapse Rate

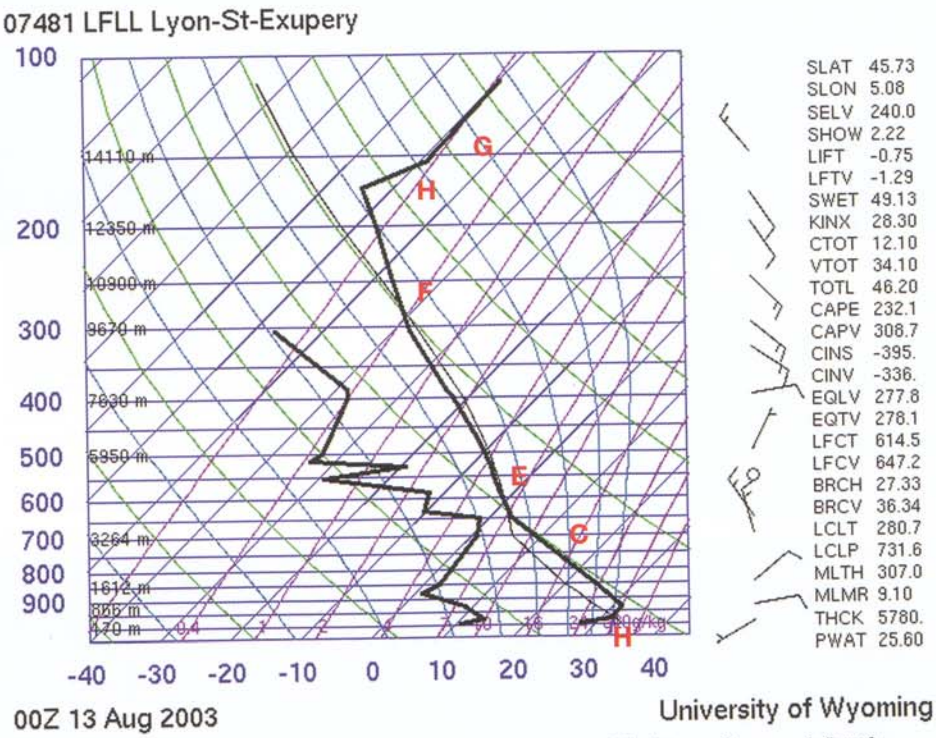

Figure 10. A sounding from Lyon, France taken at 1 am August 13, 2003 plotted on a Skew-T. The letters are the same as in figure 9.

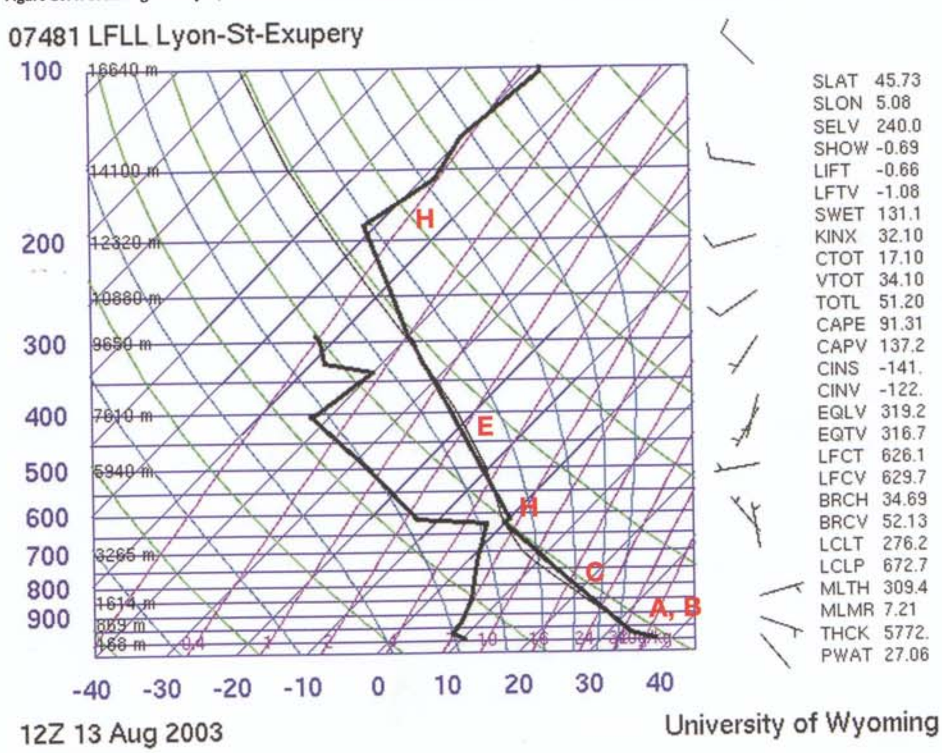

Figure 11. A sounding from Lyon, France taken at 12 pm August 13, 2003 plotted on a Skew-T. The letters are the same as in figure 9.