Aerological Measurements in the Himalaya taken from a Paraglider

Introduction

What are the differences in temperature and humidity between the air inside a thermal and the ambient air? I have found only a partly satisfactory answer to this question in the literature that I have painstakingly assembled over the years. But I always hoped one day, with improving technology, to get a small and accurate device to measure for myself the atmospheric parameters during a flight. Furthermore, it seemed to me that paragliding, thanks to its slowness and precision, would be ideal for such an experiment. At the end of 2006 the Swiss company JDC, well-known for its famous Windwatch, finally released the little jewel that I dreamed: the Skywatch GEOS 11.

After taking measurements of the famous thermal called in French “la pompe à couillon” (i.e. the thermal for dummies) in front of “Les Ruinettes” in Verbier, Switzerland in December 2006, which were published in an article of Swissglider journal in March 2007 (available on the website of the Swiss Hangliding Federation, www.shv-fsvl.ch), I carried out more experiments, in particular an amazing one in the Indian Himalayas (at the famous Bir-Billing) in October 2007, which teaches us a lot about the local aerology of the Bir-Billing flying paradise.

Materials and methods

Measuring device: Skywatch GEOS 11 whose recording flash memory is set to one group of measurements (in htis case the pressure, temperature and humidity) per second. The device is able to save up to 24,000 groups of measurements. The technical data of this device are available on the link: www.jdc.ch/fr/geos11.html. The manufacturer insists on its accuracy. It must however be protected against sunlight and in particular has to be well ventilated to get valid measurements. This is achieved by placing it in a homemade cardboard tube about 8 cm in diameter and 33 cm in length open at each end and surrounded by a 5 mm thick thermal insulation foam with aluminum foil on its outside in order to reflect as much radiation as possible (figure 1). The tube is fixed on the side of the harness so that its long axis is parallel to the flight path. Consequently, the interior of the tube receives good ventilation due to the relative wind.

Software used: Skywatch Log with USB interface allows one to download to a PC all the data recorded on the GEOS 11. The software allows for the variation of the data against time to be viewed in graphic form and for all the data to be exported as a text file. This file can then be presented in an MS-Excel spreadsheet and its data subjected to calculations and graphical representation. In particular, we can plot elevation, i.e air pressure, (y-axis) against temperature or temperature dew point (x axis). GFS model profile of the area at the same time can also be integrated into the graphs for comparison.

In addition to the GEOS 11, I use a GPS and CompeGPS software to establish the flight path and evaluate the movement of the air.

Figure 1: The JDC GEOS 11 device with the tube protecting against heating from direct sunlight.

Figure 2 shows the area of the experiment. The SW face of the Dhauladhar ridge of the Indian Himalaya, whose peaks range from 3000 to 5000m high, faces a broad plateau 800 to 1500m high that continues into the great plains of northern India. Coordinates: N32° - E76.7°. The usual landing is near the Tibetan colony (1400 m), located just below the village of Bir. The take-off usually takes place at Billing (2400 m). The thermal selected (Ther in fig. 2) is located on the small SW ridge in front of Billing.

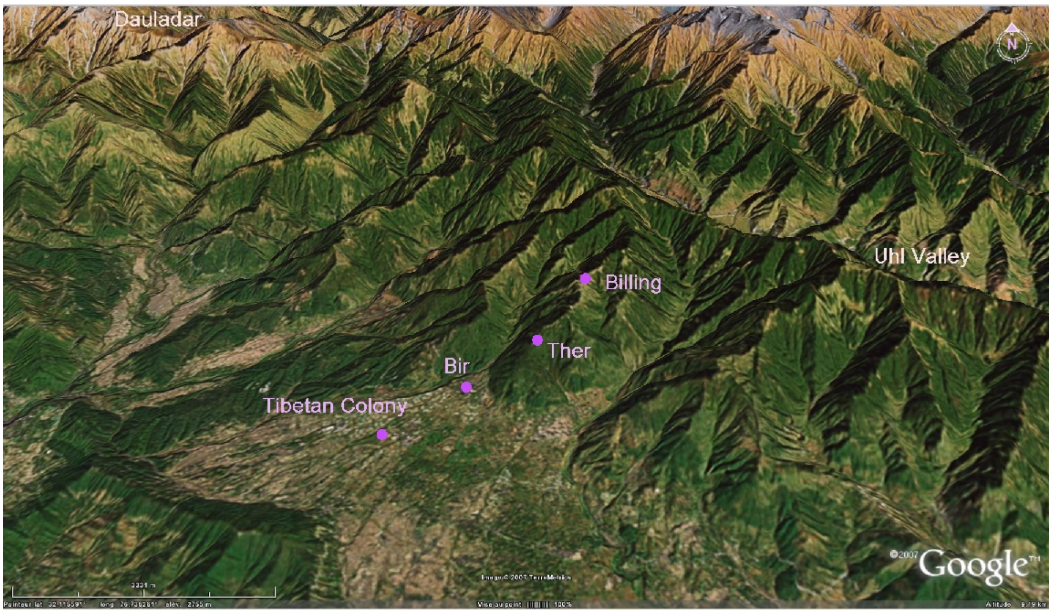


Figure 2: The area of the aerological experiment.

Unit of time used: universal time UTC (Greenwich), also known as Z. We must add 5.30am to Z to find the local time in Bir. For example 08Z30 corresponds with the local time 14h00. The experience took place between 08.00 and 09:10 Z on October 31st 2007.

After the monsoon, which brings rain and winds from the southwest and lasts from June to September, a consistent tropical anticyclonic situation persists for several weeks. The conditions for flying are good almost every day in October and November. Figure 3 shows the computed sounding profile from NCEP-GFS macroscale model analysis at the approximately same time and place as our local (microscale) aerological experiment. NCEP is for National Center of Environmental Prediction, USA and GFS is for Global Forecast System i.e. the official US macroscale meteorological prediction model, easily available from the ARL-READY website (http://www.arl.noaa.gov/READYamet.php). At macroscale level the atmosphere is extremely dry with the green curve showing dew points far from the red temperature curve. The temperature gradient up to 700 hPa is about 0.7°C/100m. The winds generally blow from the northwest at 10-15 km/h. These weather features are typical and very frequent at this period in the region. Locally and at flight altitudes (approximately 2000-4000m) the Dhauladhar ridge seems to protect from these northwest winds however. Pilots almost never feel these synoptic winds in front of the sunny southwest Dhauladhar faces where weak to moderate regional (mesoscale) thermal breezes from the southwest (to be described below) dominate. The daily observation of residue from the tops of cumulus clouds generated by the high Himalayan peaks confirms the general quasi-permanent northwest winds at higher altitudes.

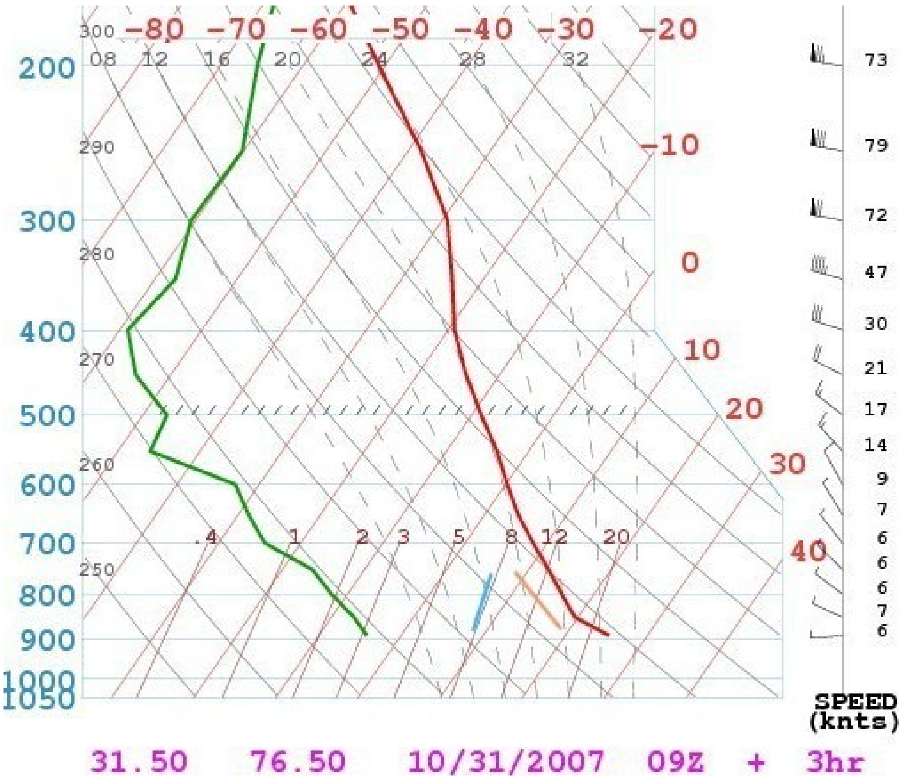


Figure 3: The NCEP-GFS computed profile about near and during the experiment.

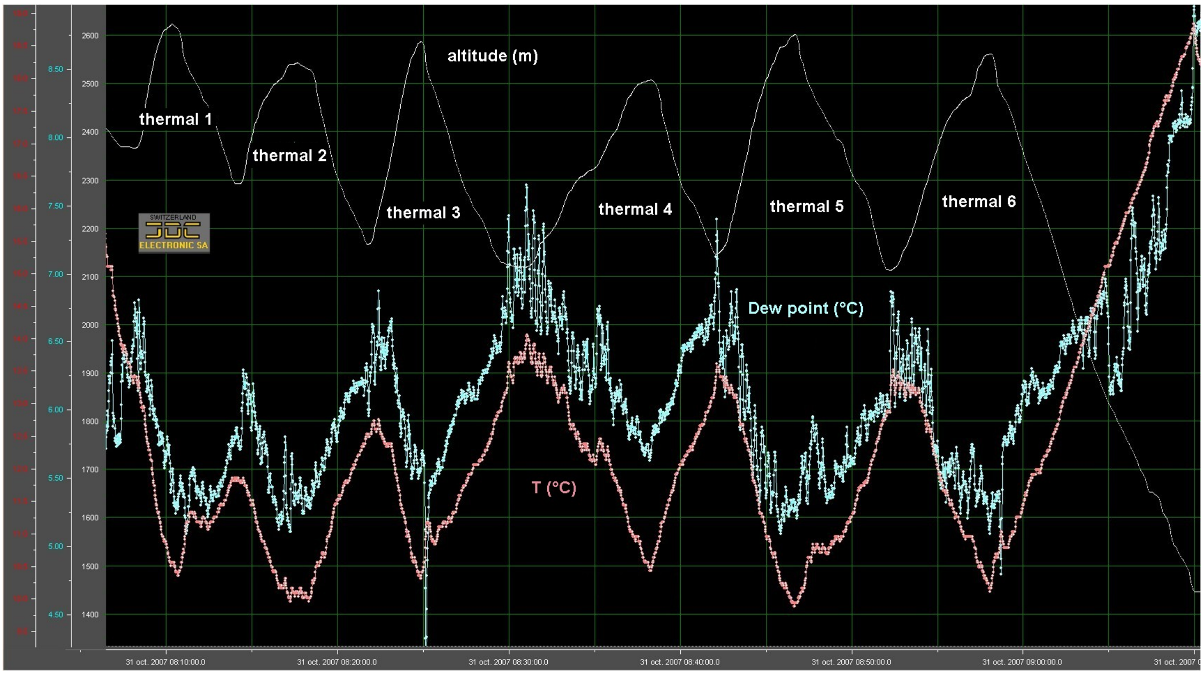


Figure 4: The time-dependent graphs from the GEOS 11 software.

Figure 5: Picture of the ridge where the studied thermal releases from the ground.

Results

The blue thermal (in ther, fig. 2) is climbed six times in succession (figure 4). The third climb (thermal 2 in figure 4) (08:22:00 to 08:24:30Z) and the third descent (08:25:00 to 08:29:30Z) as well the final descent (08:58 to 09:10Z) above the landing place seem to be most interesting. Among the six climbs only the fourth is a little weaker and irregular. The thermal can therefore be considered as a column of air rising almost continuously over the deflection in the ridge, marked by a bend in the road to Billing (Figure 5). On my almost daily way on foot up to Billing, I observed irregular breezes on the slopes under the bend, sometimes coming from one place, sometimes from another, then probably alternately feeding the more regular thermal column aloft (see later and figure 10). Figure 6 shows the vertical profile of the atmosphere during the final descent. Below 2100 m, the temperature gradient is very close to the dry adiabatic lapse rate (DARL). Between 2100 and 2500m the gradient weakens and gradually approaches 0.6 ° C/100m but it is difficult to conclude definitively about the T-gradient because for these altitudes the flight was mostly in a horizontal direction in order to approach the landing place. The gradient of measured dew point is very close to the dew point line (0.2°C/100m), indicating a very homogeneous moisture in the convective boundary layer. This aspect of the two curves is consistent with the classical structure of that layer. If we put them on the diagram in Figure 3 (the blue and orange lines), we are struck by the discrepancy between these microscale measurements and the macroscale lines (red and green) from the NCEP-GFS analysis. The lower atmosphere at the local level is much more humid and slightly cooler than that at the synoptic scale. Figure 7 shows the GPS trace of the third ascent and descent, respectively inside and outside the thermal, projected on both horizontal plane and vertical plane (profile). The rise is presented in detail in Figure 8. The color gradient is modulated by the vario: yellow- orange = 1-2 m / s, red = 3-4 m / s. In the lower third, the ascent is inclined by a southwesterly breeze of 5-10 km/h, gradually decreasing with height. In the middle third, there is no breeze so the thermal is vertical and regular with a maximal strength (about 4 m / s). Above the small inversion (see later) at 2500 m, the ascent is inclined by a NE wind and is more irregular and turbulent resulting in color variations of the track.

Figure 9 shows that within the thermal the air is 0.3-1°C warmer and 0.2-0.6°C (dew point temperature) more humid than ambient air. Above the inversion (2500 m) there is no difference in temperature but an emphatic difference in humidity. The temperature inversion is small (0.3°C over 50 m) and is only highlighted by the measurements at the beginning of the descent with the small typical "S" temperature curve (red) and low humidity (dark blue curve) at altitude 2500 m. The ascent has therefore probably crossed this inversion because of inertia and also perhaps because the moister air in the thermal is a little lighter than the drier ambient atmosphere. Nevertheless difference of temperature plays a much bigger role in buoyancy of the thermal than the difference of humidity.

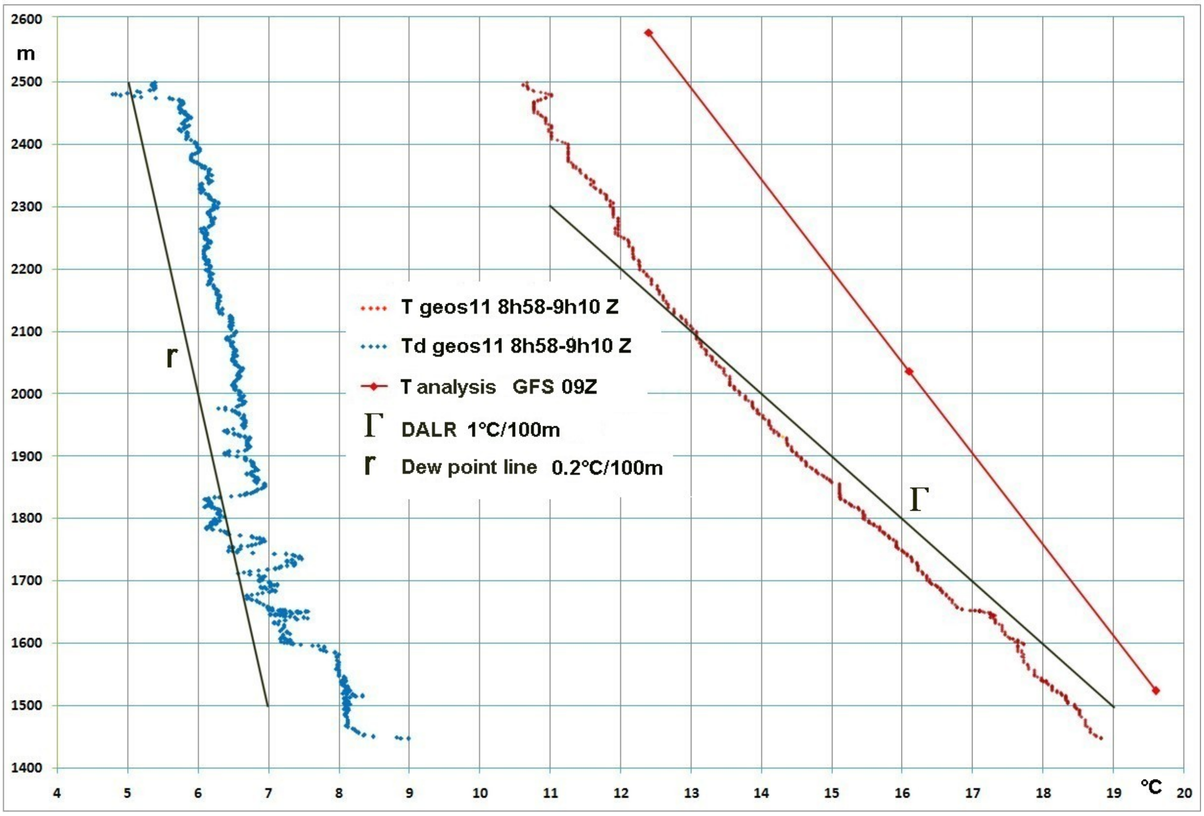


Figure 6: The measured profile (temperature and dew point) of the final descent.

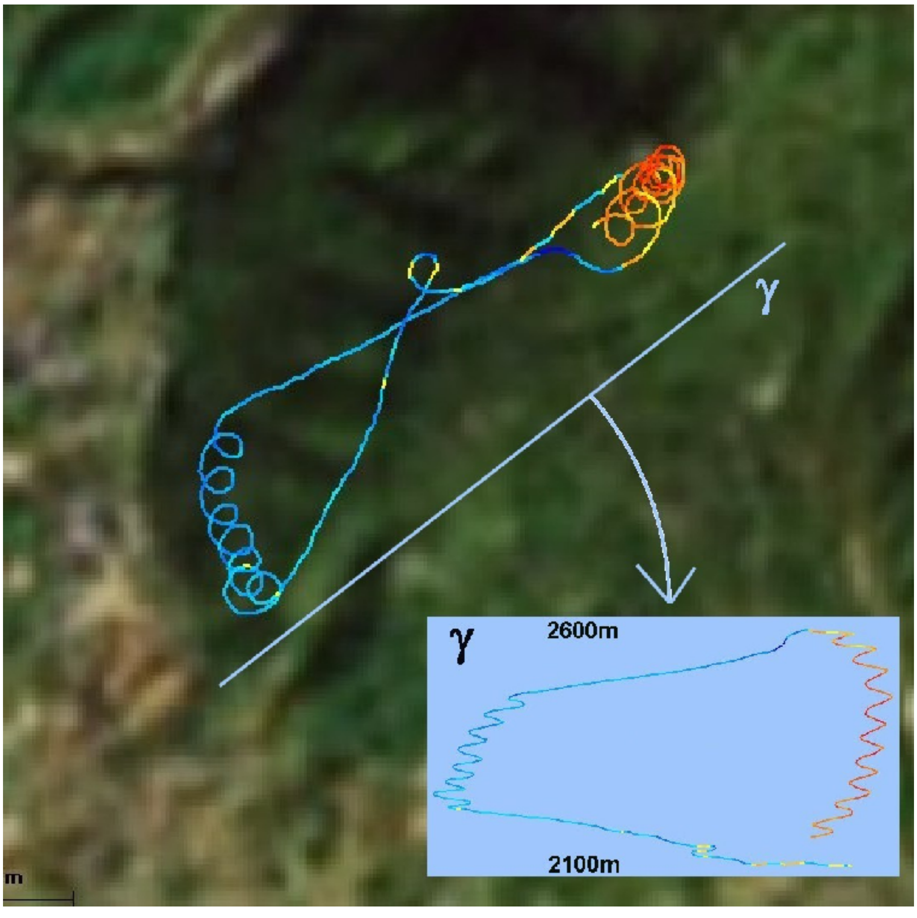


Figure 7: GPS track in the studied thermal.

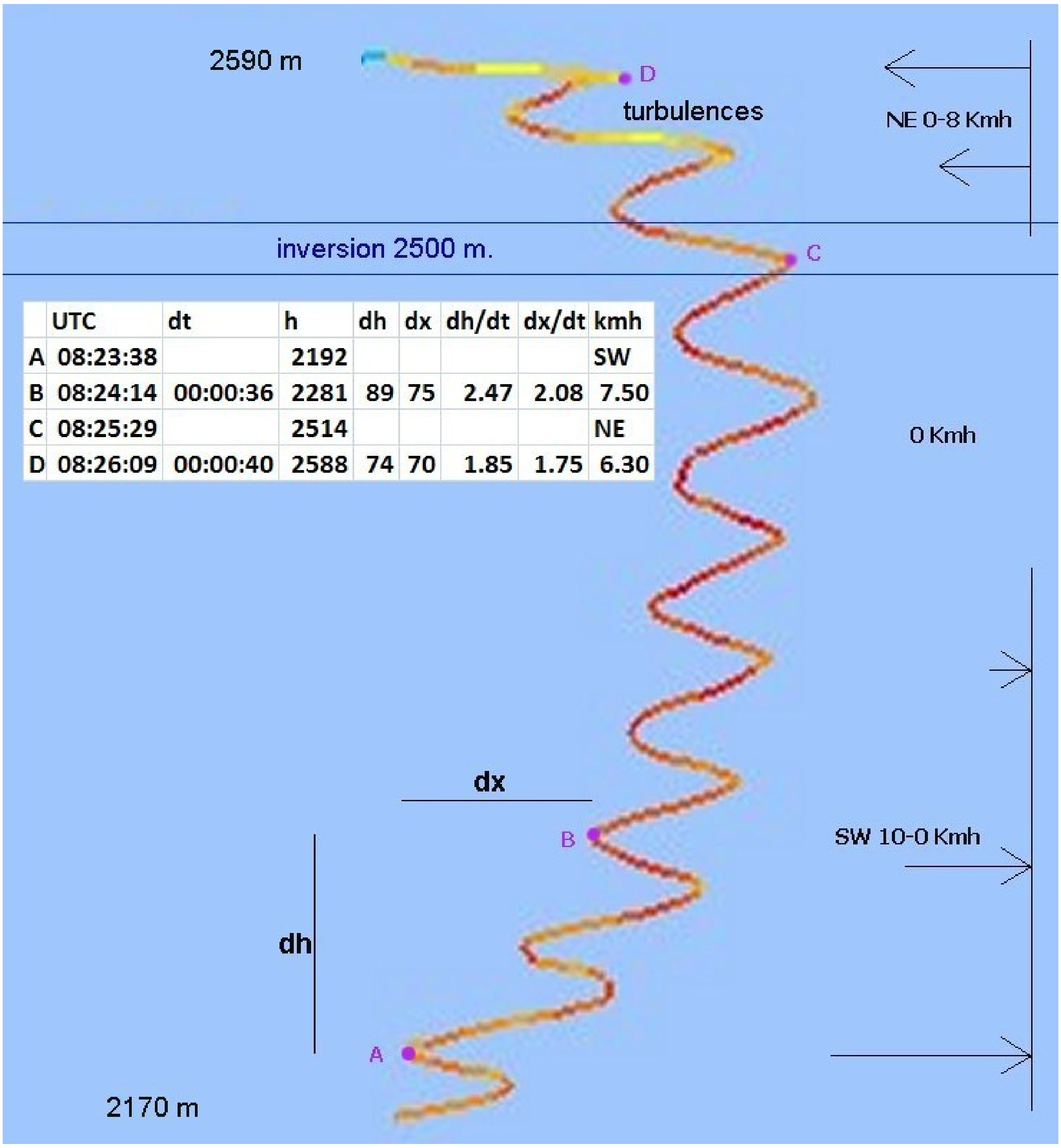
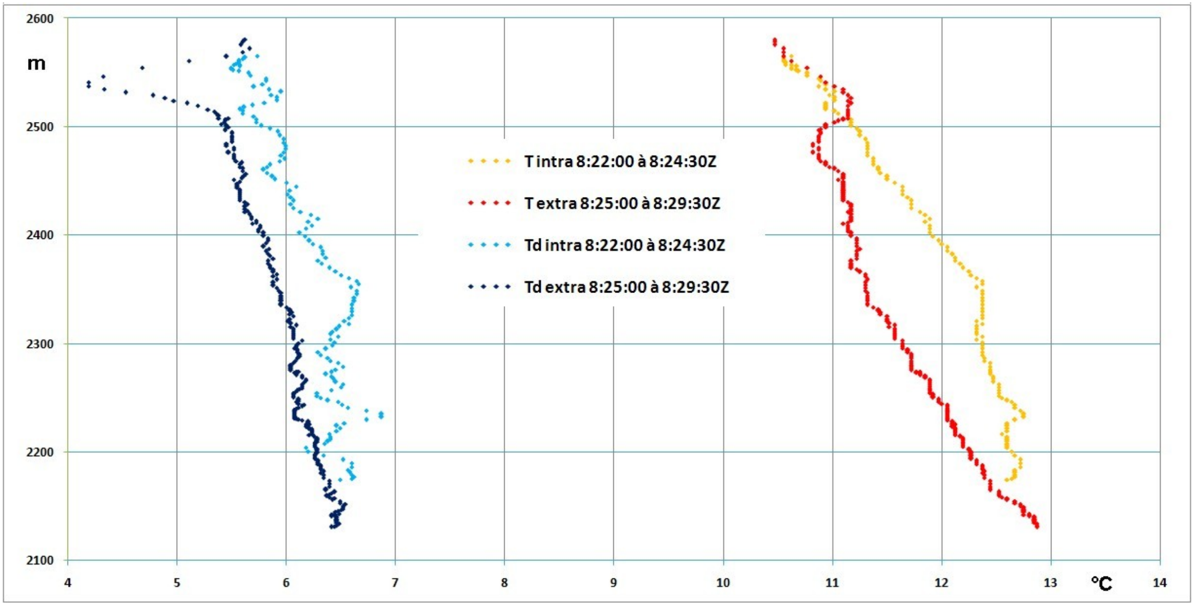
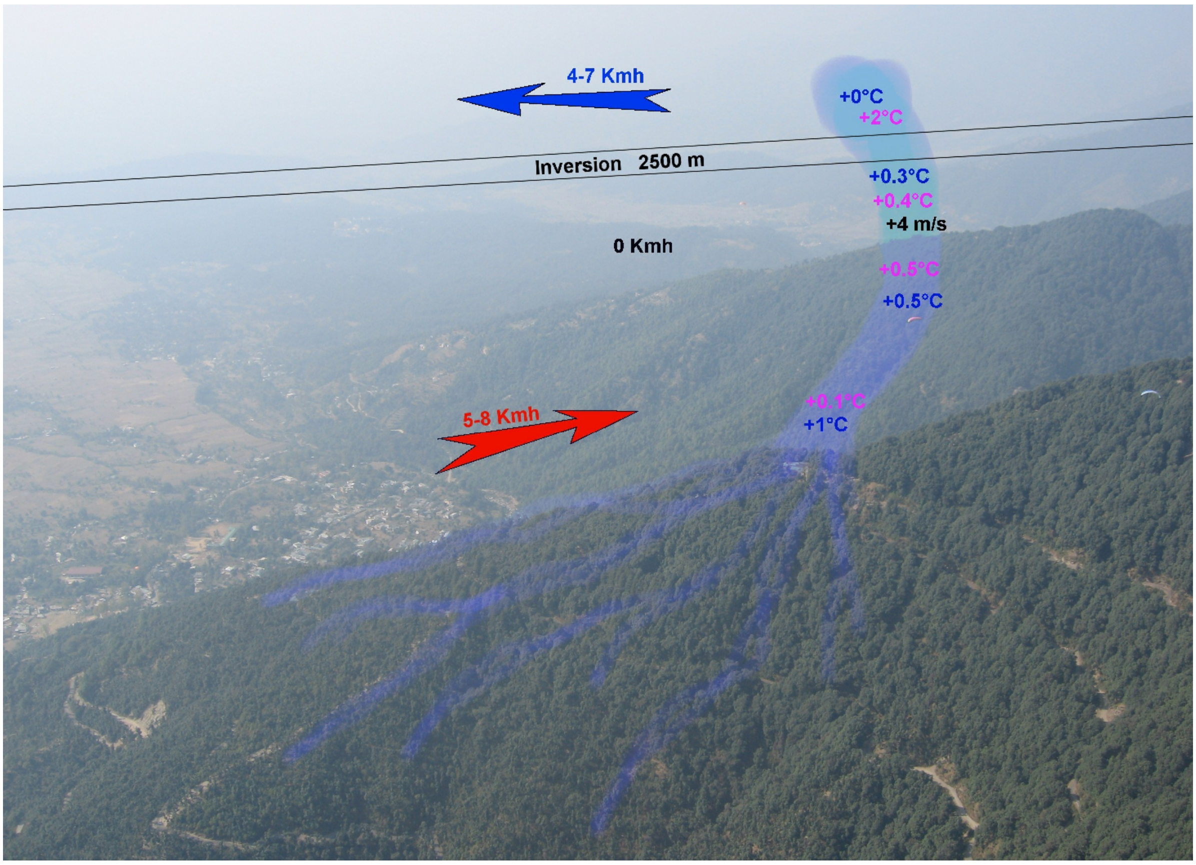


Figure 8 (above): Details of the GPS track.

Figure 9 (next page, above): The measured profile (temperature and dew point) of the thermal (inside and outside).

Figure 10 (next page, below): Microscale model of the thermal and its convective boundary layer. Blue numbers = temperature differences. Pink numbers = dew point differences.





Interpretation and conclusions

We can now imagine a model of our thermal and its boundary convective layer at microscale level (Figure 10). At the bottom of this layer, a regional (mesoscale) SW anabatic breeze leads the thermal to incline towards the mountain. At the upper half of this layer there is no wind, so the thermal becomes vertical. A small inversion is likely often to mark the top of the layer and just above the wind blows in NE direction, therefore exactly in the opposite direction to below. The thermal regularly takes the form of a continuous rising column of air from the bottom ridge where several irregular small packets of hot air, sliding up the sunny slope, finally converge together to form the thermal, as multiple converging small drops sliding down around a hanging conical stalactite to finally take off and form the downward stream of water. The thermal can sometimes cross the inversion, which is a few tens of meters thick, essentially by inertia and it becomes significantly more humid than ambient air. Below the inversion, the differences in temperature and humidity between the rising air and ambient air are not very important. This microscale model seems to show that if you look for speed-to-fly performance, you should not waste your time to try to climb higher in the thermal if you feel, after a good vertical ascent, a turbulent weaker climb which is tilted by NE wind.

Moving from local (microscale) to regional scale (mesoscale), the circulation model is shown in figure 11. We note three layers of winds. The two lower layers, purely regional and therefore not visible in the synoptic “shortsighted” analysis of the NCEP-GFS models, offset kinetically together in the form of a "treadmill". Their directions differ by 180° (SW versus NE). In the upper layer (above 3000-4000m) a synoptic general NW wind, perpendicular to the regional breezes below, is visible by the macroscale NCEP-GFS analysis. Professor Neiniger of the ETHZ (Local winds in the upper Rhone Valley. Geojournal, 1984) studied a similar phenomenon in the Swiss alpine Goms valley (the area of the famous flying site Fiesch). He highlighted two lower local breezes, parallel to the longitudinal axis of the valley, but opposite in direction, and an upper third layer of wind depending on the general weather situation.

The "myopia" of the synoptic NCEP analysis is ultimately demonstrated in Figure 3 by the fact that locally in the lower layer, the air is slightly cooler (orange curve) and much wetter (blue curve) then the macro-scale curves (respectively red and green curves). This can be explained by the convergence of anabatic breezes on the ridges leading to a slow regional and global uplift of the air mass and the formation of a thermal depression (LOW in figure 11), which cools and moistens the air mass and increases its instability. To compensate, there is subsidence of the air on the plateau (HIGH), which strengthens the aloft temperature inversion at this level. Therefore, we can now understand why, despite a very dry atmosphere being heralded by the macroscale numerical models, we can observe large clouds on the Dhauladhar. Thus, from a picture taken from Billing towards the northwest and the NCEP-GFS synoptic sounding profile at about the same time and same place (Fig. 12), we can imagine the local temperature (orange) and dew point (blue) curves.

A fact we can observe almost every day is that cloudbase lowers as the day progresses. For example the small cumuli are very high in the morning above the ridge of Dhauladhar at about 4000 m or higher. From noon to afternoon, as the cumulus become progressively bigger, the cloudbase sinks to 3000 m and sometimes even lower. I do not have enough measurements to prove the cause of this phenomenon we usually do not observe in the Alps. My hypothesis is that in the morning there is a strong low inversion above the plateau in front of Dhauladhar, keeping the very moist and hazy air in a thin convective boundary layer which cannot continue with the hat-shaped drier and cleaner layer around the high sunny slopes. Above these slopes thermal can develop easily and early with a very high level of water condensation. During the afternoon, when SW regional breeze blows, the boundary layer of the plateau continue in that of the ridge, bringing moist, hazy and polluted air from crowded area with restless human activity (traffic, farming of wet soil, fires) to the Dhauladhar’s slopes. See fig.13.

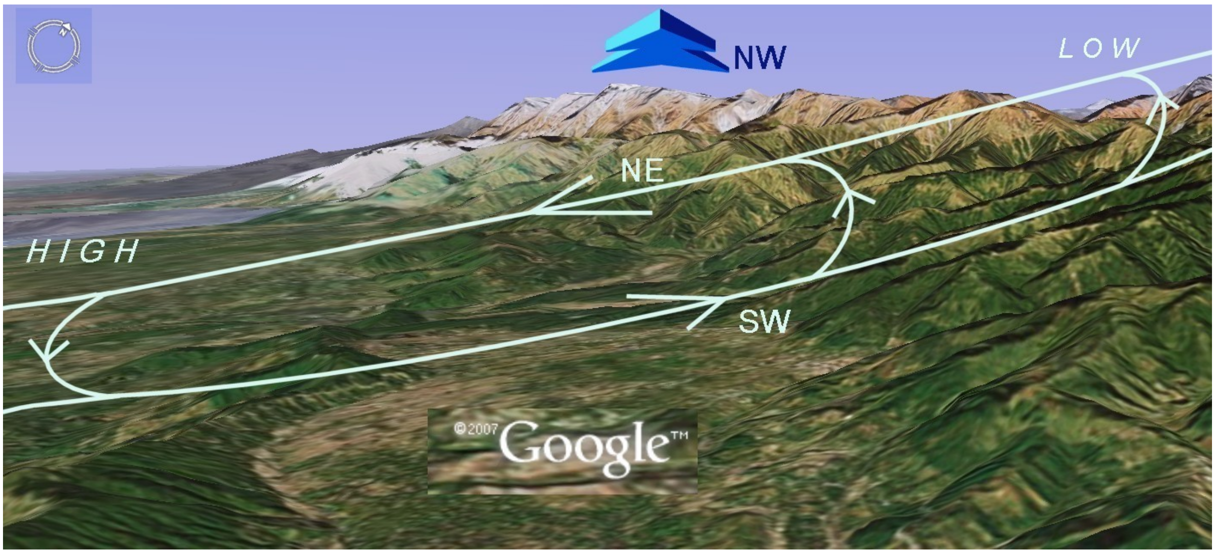


Figure 12: Mesoscale model of the regional aerology.

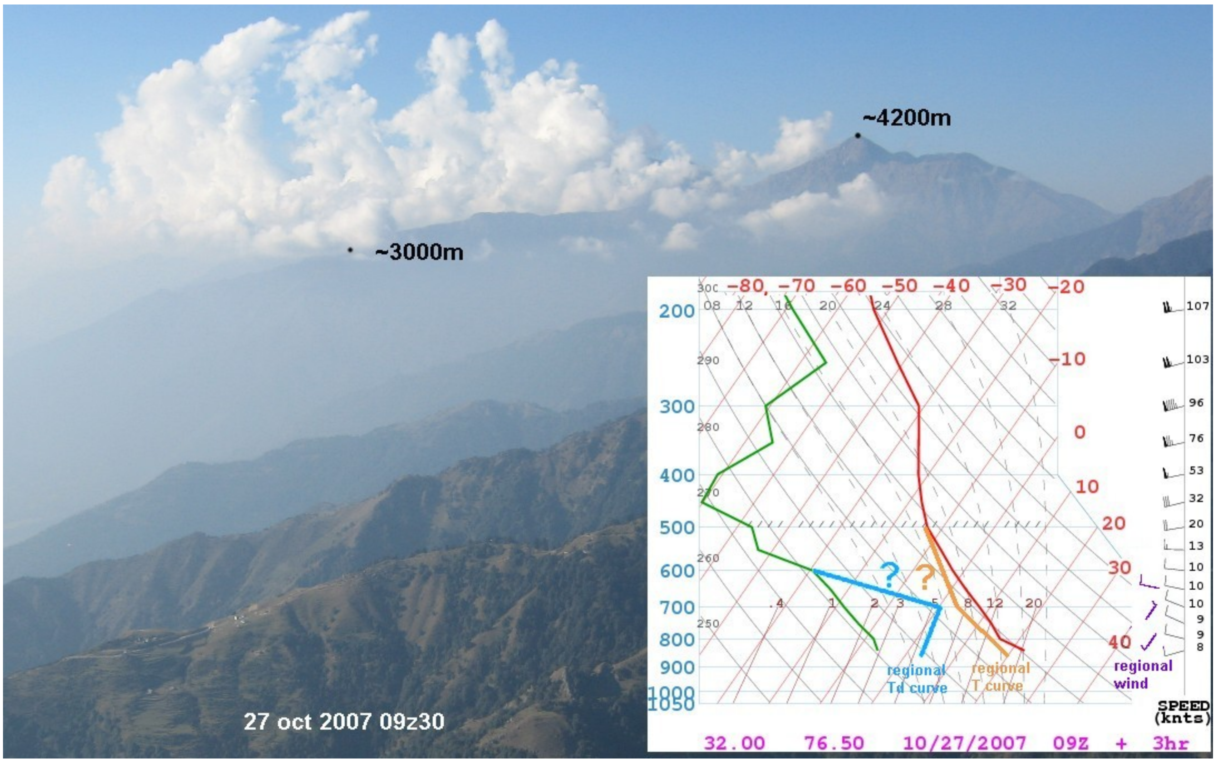


Figure 13: Another day as an example. We can imagine the microscale local profile from the observation of the sky and the macroscale model profile.

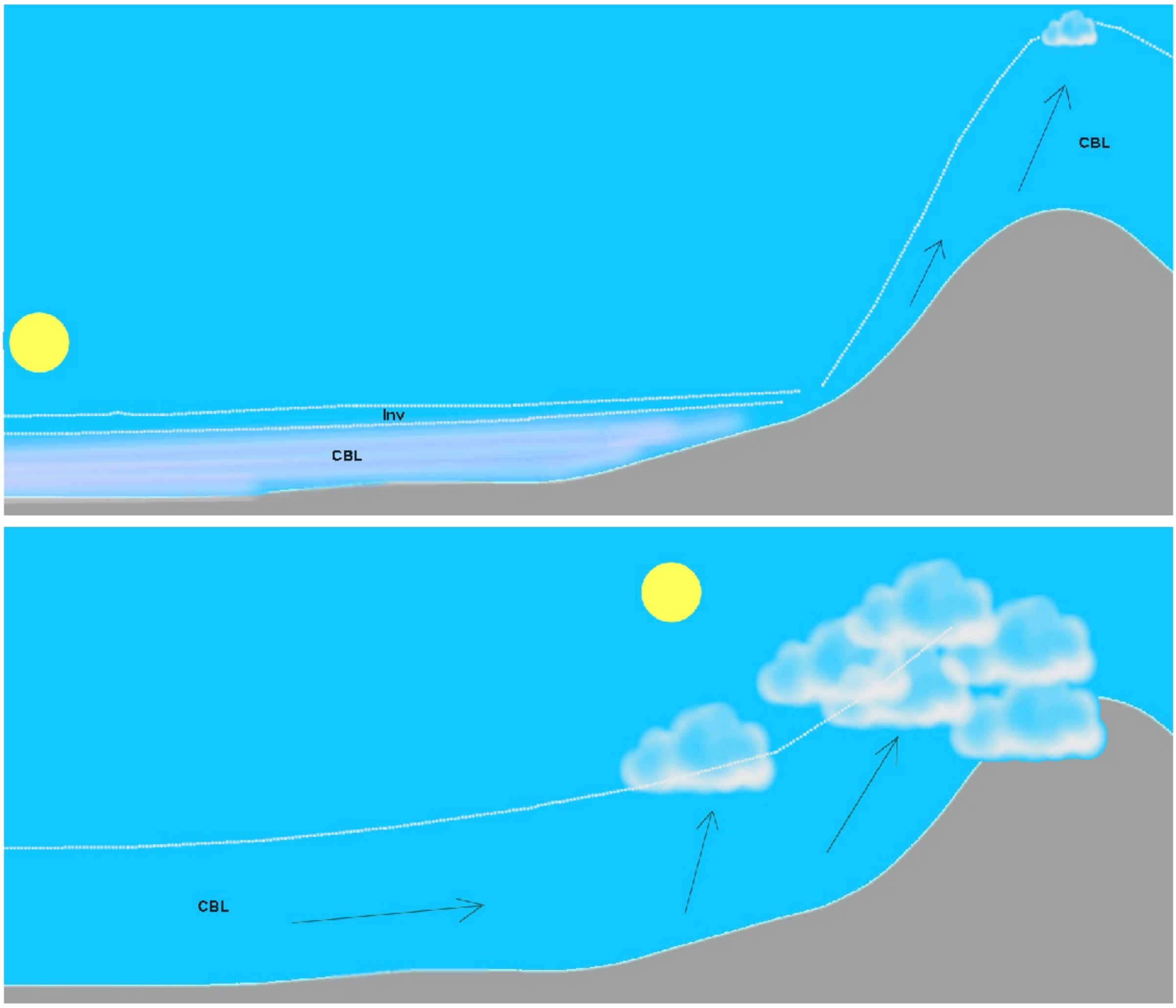


Figure 14: Hypothetical explanation of the cloudbase's lowering in front of Dhauladhar as the day progresses. CBL = convective boundary layer. Inv = temperature inversion.

Jean Oberson, spring 2009.

Thanks to Jim Mallinson for suggestions and english language correction!