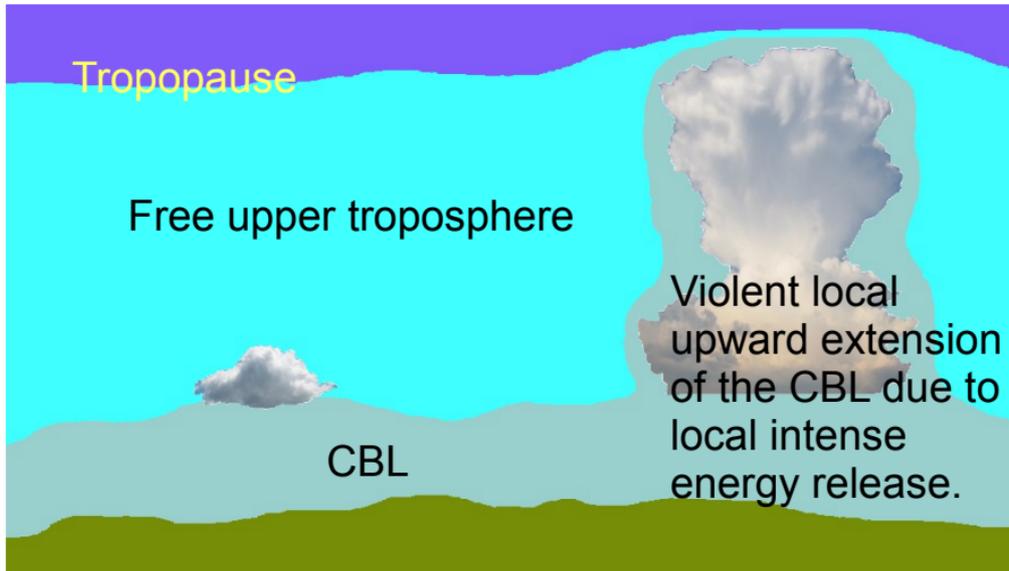


What is the convective boundary layer ?

The convective boundary layer (CBL) is the lower tropospheric layer on contact with the ground. Its depth varies from a few meters to a few kilometres (more than 4 km) according to seasons, locations, winds, meteorological conditions and incoming solar radiation. Our thermals (dry atmospheric convections) take place in this layer only.

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The CBL is now a well understood, documented and approved concept in the scientific scene.

Furthermore, CBL is omnipresent in the numerical weather models computation and outputs.

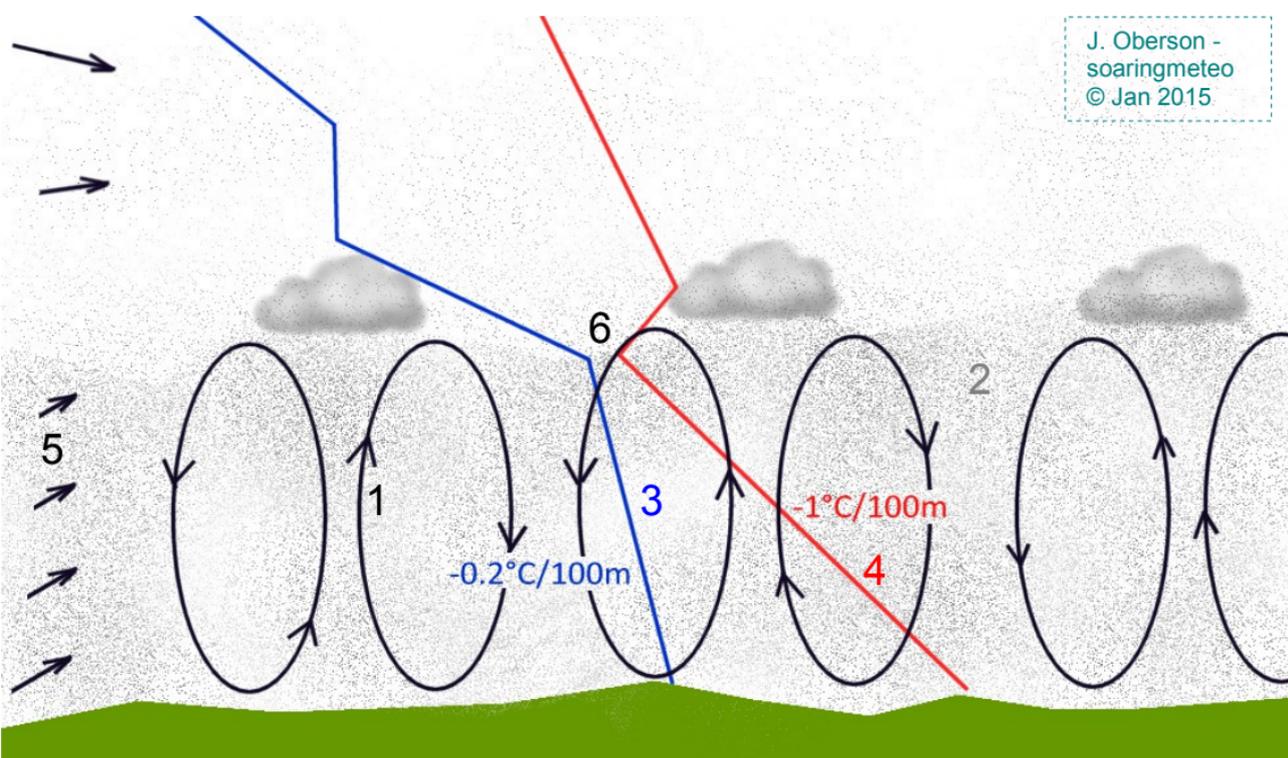
Thus, it is essential to include this pattern in the aerology teaching and research if pilots want to progress in meteorology.

Nevertheless and unfortunately, there are still a lot of viscous conservative mental reactions and resistance among pilots, flight instructors and experts to include the CBL into the science of aerology.

Above the CBL, the free troposphere extends up to the tropopause.

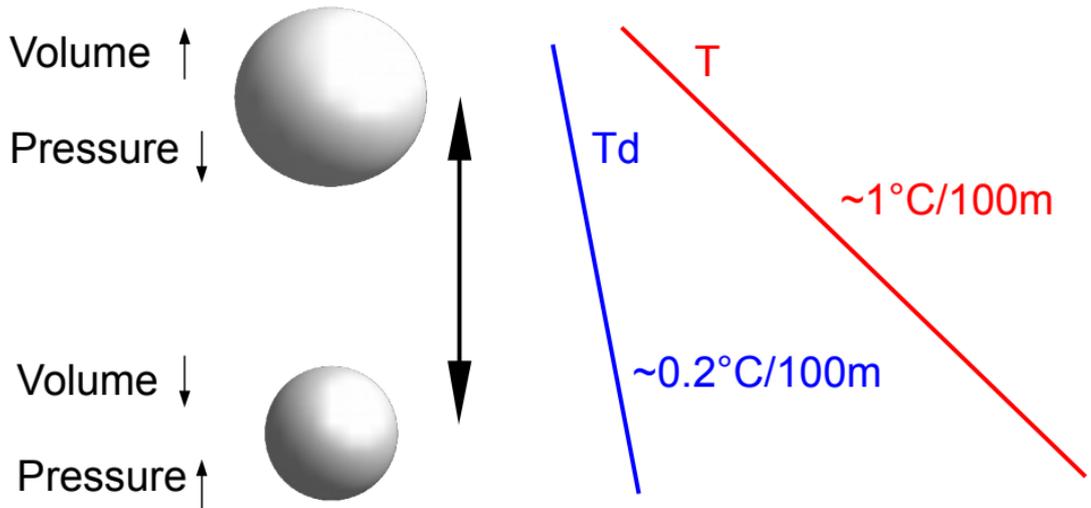
Here is a summary of the 7 main properties of the CBL resulting from its close contact with the Earth's surface:

1. It is turbulent because there are incessant ascending and descending vertical air motions (our dear thermals). Therefore, this layer has an important air mixing, leading to frequent contacts with the underlying ground and resulting in the other following features.
2. It is particularly rich in aerosols (dust) which gives it its hazy appearance.
3. Its moisture content is uniform and stronger than the free atmosphere above. The dew point lapse rate inside it equals about $-0.2^{\circ}\text{C}/100\text{m}$.
4. Its temperature lapse rate is homogeneous and equals about $1^{\circ}\text{C}/100\text{m}$ (adiabatic lapse rate). Its upper limit is often marked by a air temperature inversion and a sudden drop in humidity.
5. Its winds are often homogeneous (same direction and speed) with a slight decreasing speed tendency with altitude.

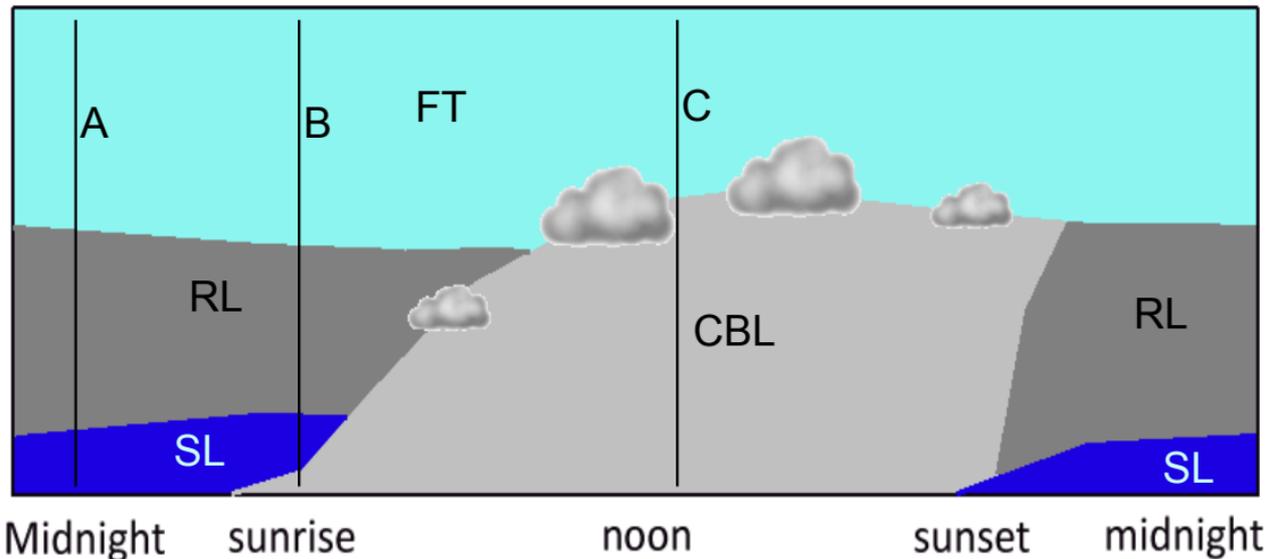


6. The difference between temperature lapse rate and dew point lapse rate results in highest humidity of the air at the top of the CBL and thus in the development of cumuli at this level.
7. The top surface of the CBL is not flat but bloated and fuzzy.

Because an air particle, subject to vertical motion, heats and dries (descent) or cools and moistens (ascent) at about $1^{\circ}\text{C}/100\text{m}$ (dry adiabatic lapse rate) and $0.2^{\circ}\text{C}/100\text{m}$ respectively, it is not surprising that the atmospheric temperature (T) and dew point (T_d) lapse rates do equal these values into the CBL, where incessant vertical, mixing and turbulent air motions do take place.

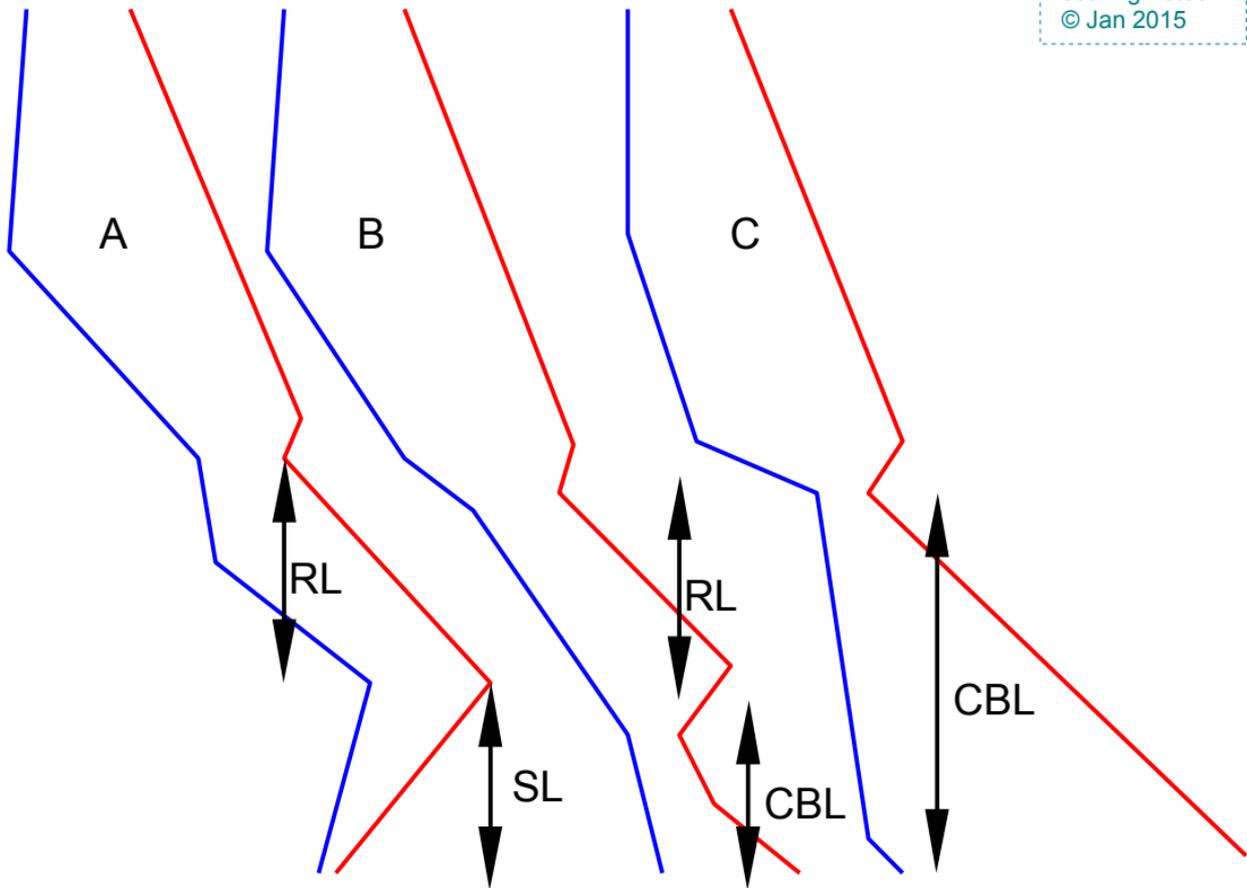


Diurnal evolution of the CBL :



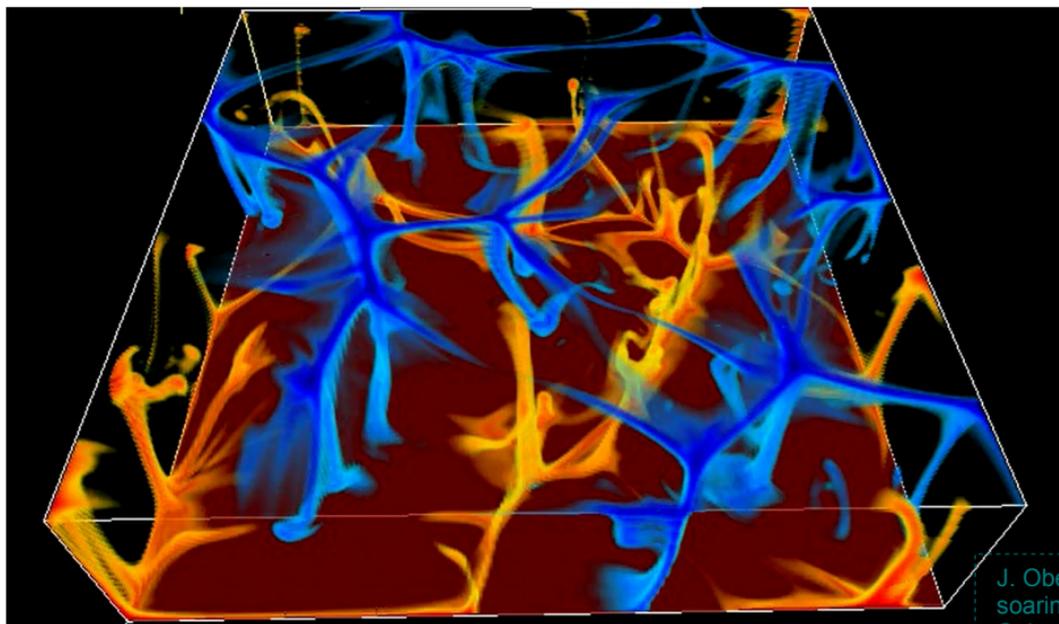
Here is an ideal case when synoptic meteorological conditions do not change from days to days.

FT = free troposphere. RL = residual layer = upper residual nocturnal still CBL. CBL = convective boundary layer = diurnal mixing turbulent layer. SL = stable layer = nocturnal ground air temperature inversion.



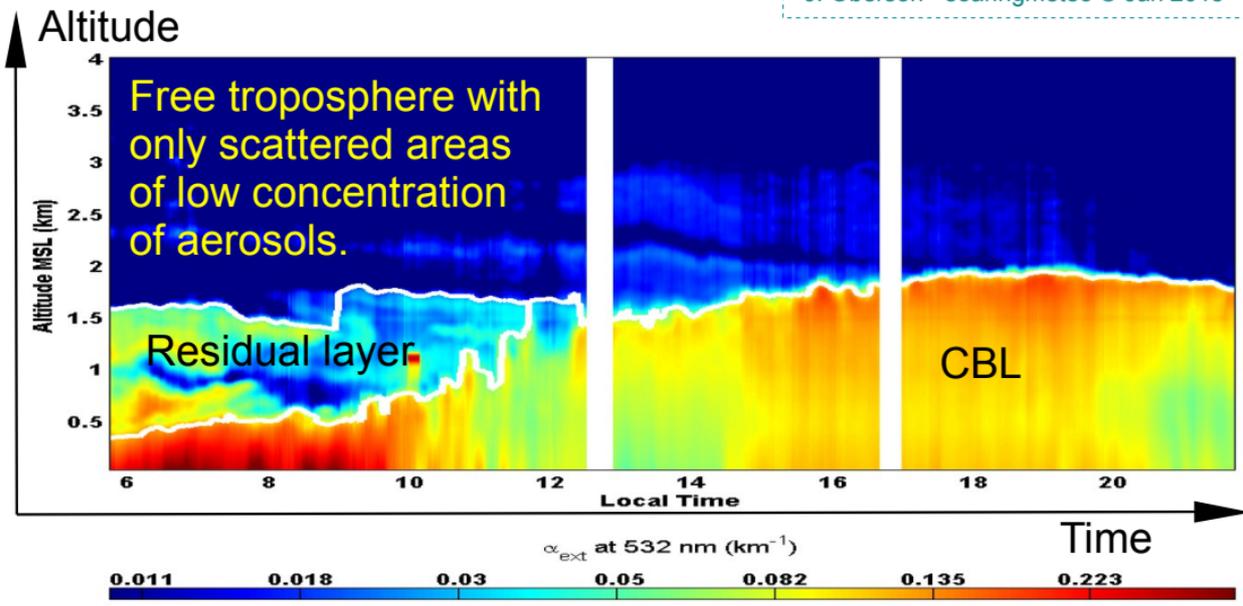
The 5 next pages clearly reveal and prove the existence of the CBL, by computer simulation, measurements and LIDAR imaging.

The lower 3D images is the result of computer simulation of CBL. The CBL layer is highlighted by downward (blue) and upward (red) vertical air motion inside it.



The LIDAR is a complex electronic device, emitting LASER light and receiving its echo from aerosols (air dust). A vertical cross sectional image of aerosols concentration is thus obtained. Because high concentration of aerosols is encountered in CBL, this latter is easily revealed by the LIDAR image, as seen on the lower image.

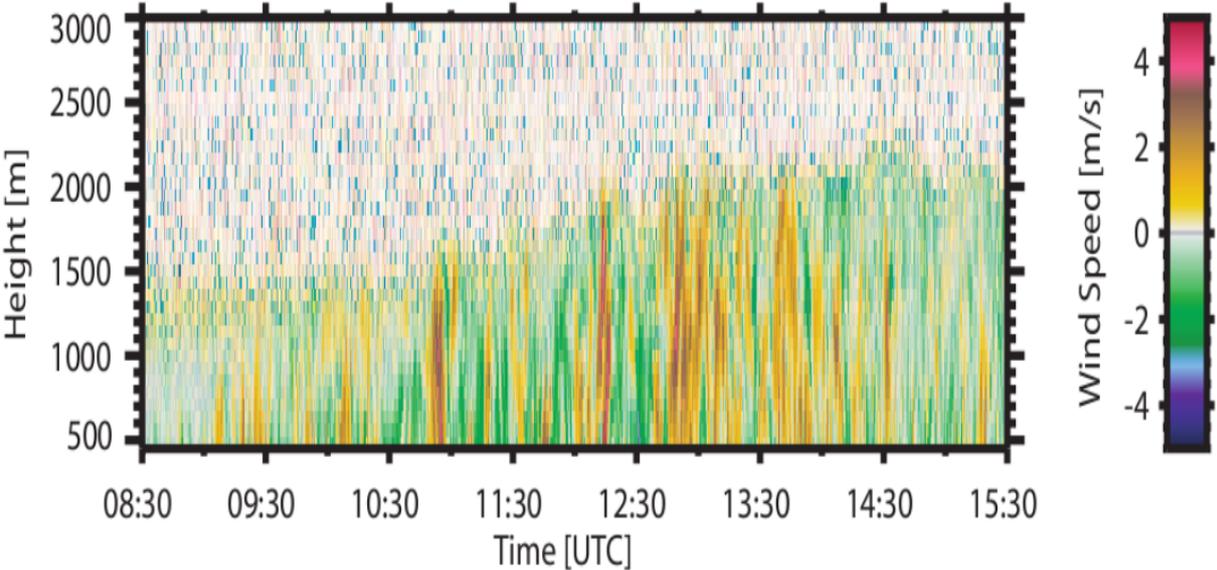
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The Doppler LIDAR provides a cross sectional image of aerosols (and thus air) motion. On the lower Doppler LIDAR image, the device is placed to highlight the vertical atmospheric motions. The difference between CBL (several strong vertical air motions) and free upper troposphere (rare weak vertical air motions) is striking.

5 July 2006

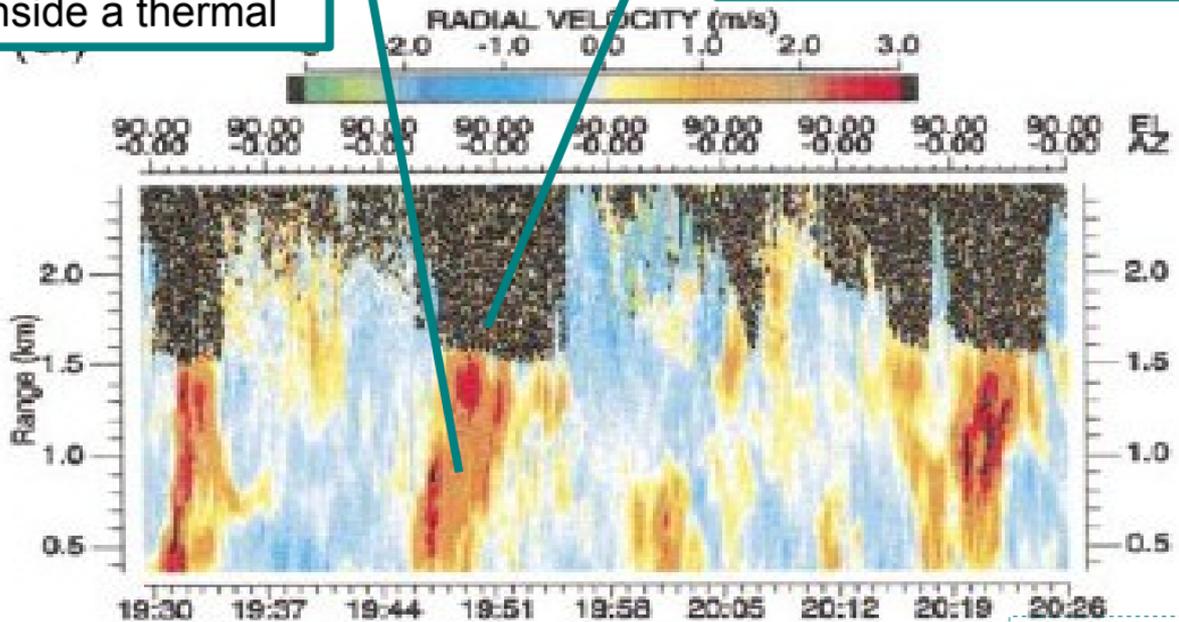
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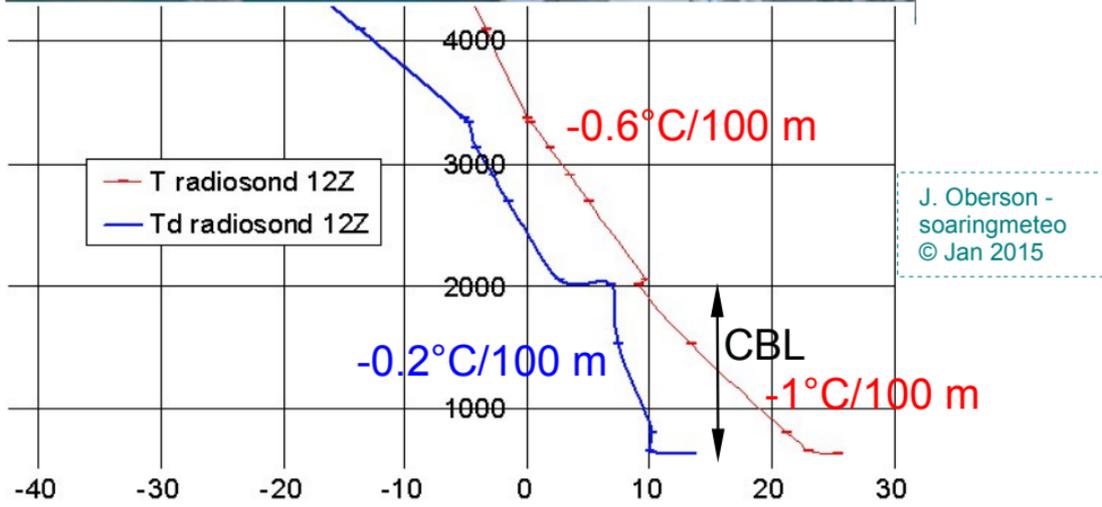
Here is another very nice and interesting Doppler LIDAR image:

Heterogeneous red signal of vertical air motion inside a thermal

Cumulus fully reflecting the LASER beam thus leading to a shadowed area behind it.



Webcam's sky picture and radiosonde in the Madrid area on June 18 2006. It looks like a good thermal soaring day with a nice CBL.



Free troposphere = clear



Top of the CBL



CBL = hazy

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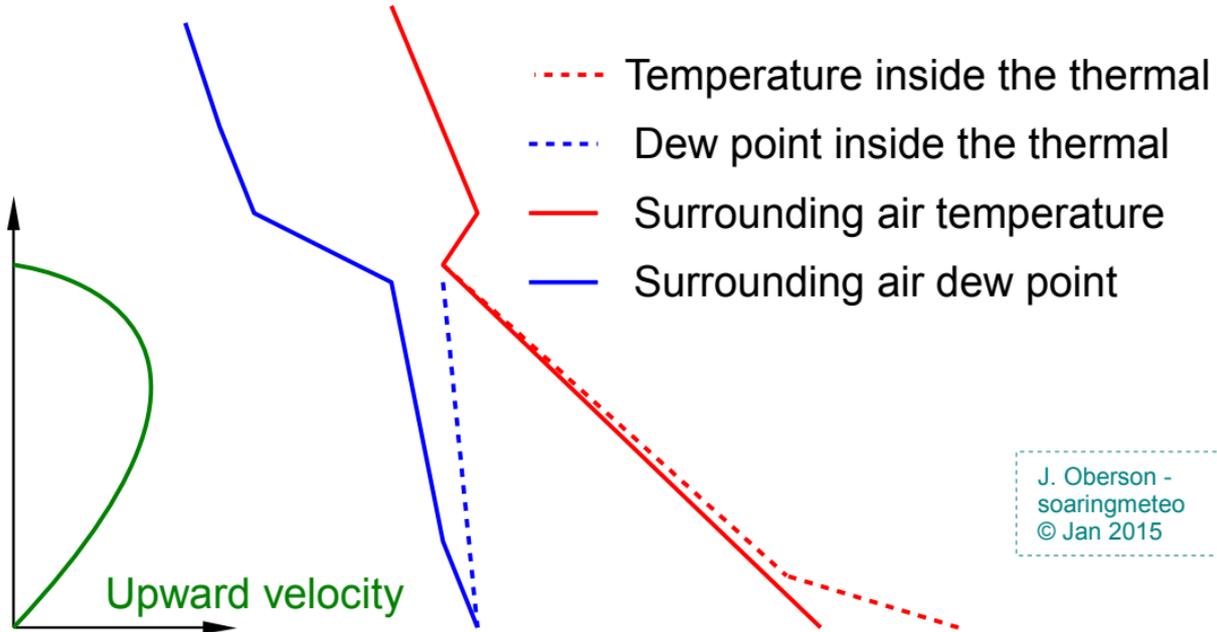
Cumuli at different heights
reveal that the CBL
follows the topography.



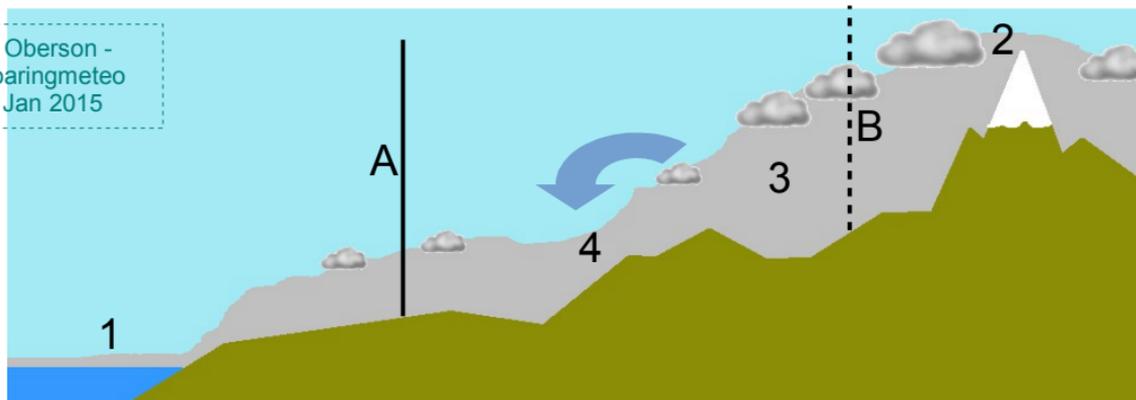
Top of
the CBL

Ground
surface

Many scientific authors (e.g. Lindemann, 1981) have clearly shown that the temperature difference between CBL's surrounding air and thermal is detectable just above the ground only. On the other side, difference of moisture is better observable at the upper part of the CBL. So probably, the start pulse of the ascending thermal motion is due to temperature difference, then the motion is sustained by inertia and by moisture difference.



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In summer and spring the CBL usually follows the shape of the topography. There is some exceptions: 1/ On a large body of water and 2/ on the highest peak, where solar heating of atmosphere from the ground is weak, the CBL is thin. 3/ On a large area of middle mountains, the CBL can be deeper with strong thermals due to an efficient solar heating. 4/ Over the foothills of a mountainous massif, the CBL can be slightly thinner than elsewhere due to the return downward flow from the massif, except if this massif is not well heated by solar radiation (snow cover in spring, heavy cloud cover).

There are interesting differences between profiles A and B :

About the same curves at very high altitude.

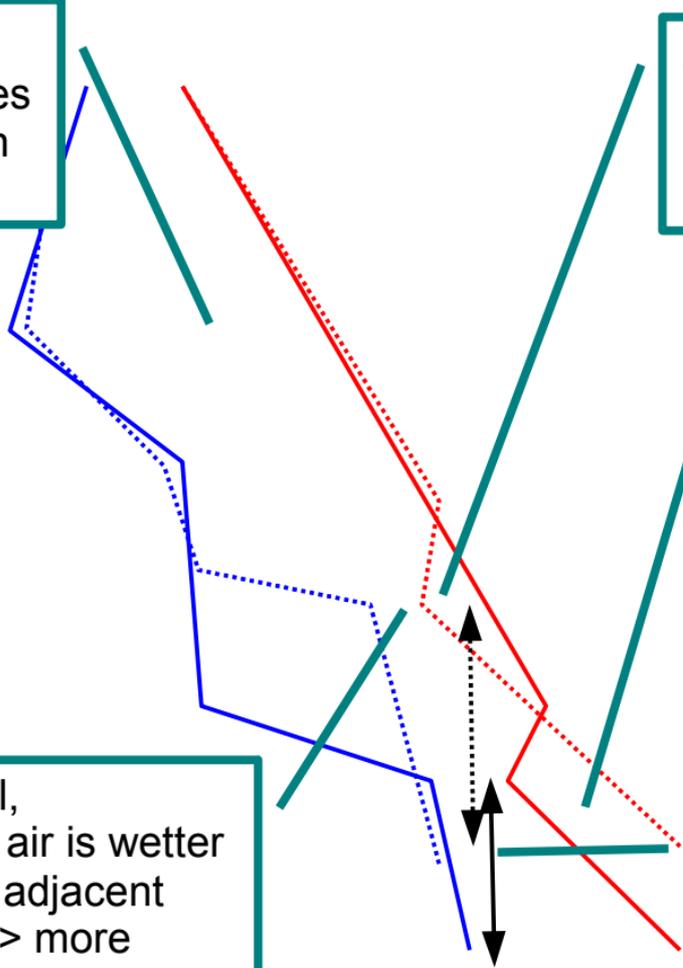
At this level, mountain's air is cooler than air on adjacent flat lands.

At this level, mountain's air is warmer than air on adjacent flat lands.

Mountain's CBL is deeper than CBL on adjacent flat lands.

At this level, mountain's air is wetter than air on adjacent flat lands => more chance of big cumuli.

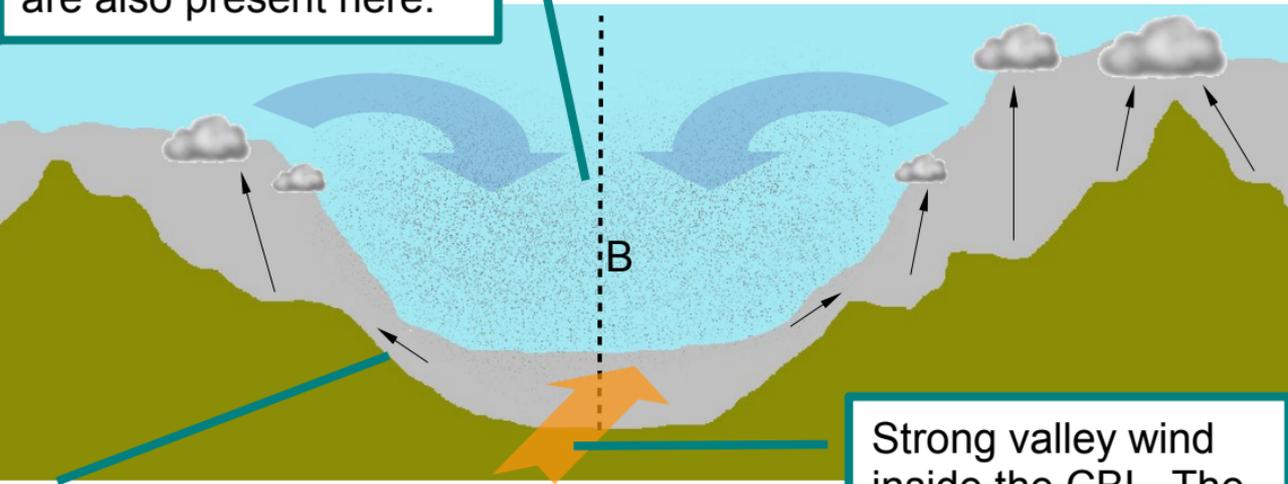
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Inside a large and deep valley, the CBL has some features :

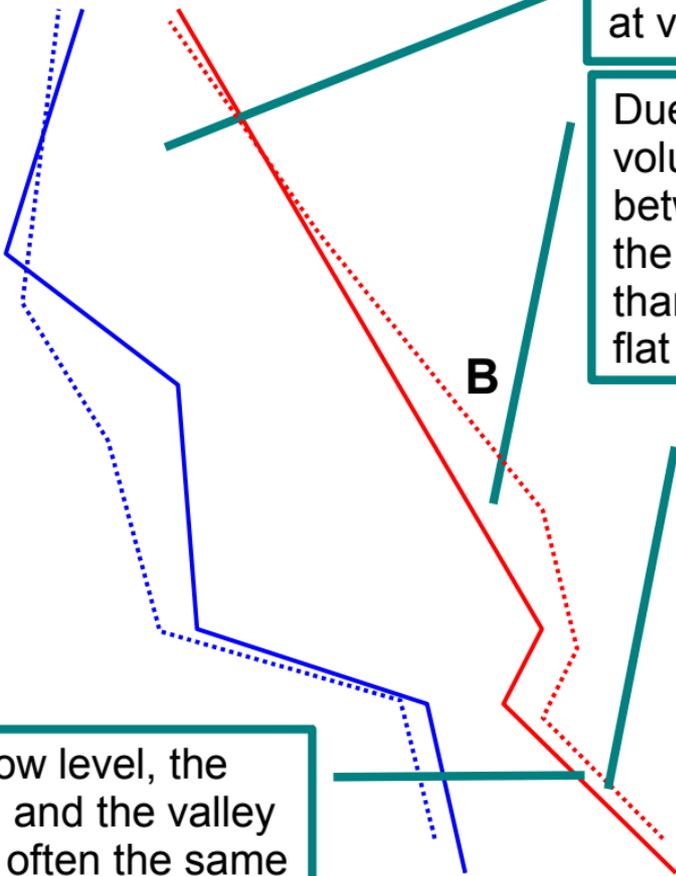
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Subsidence in the middle of the valley above the CBL. Aerosols are also present here.



Probably due to subsidence, the CBL is thin on the lower valley side slopes. Thus the thermals are here rare, weak and turbulent.

Strong valley wind inside the CBL. The thermals rising from the bottom of the valley are often hashed by this wind.



About the same curves at very high altitude.

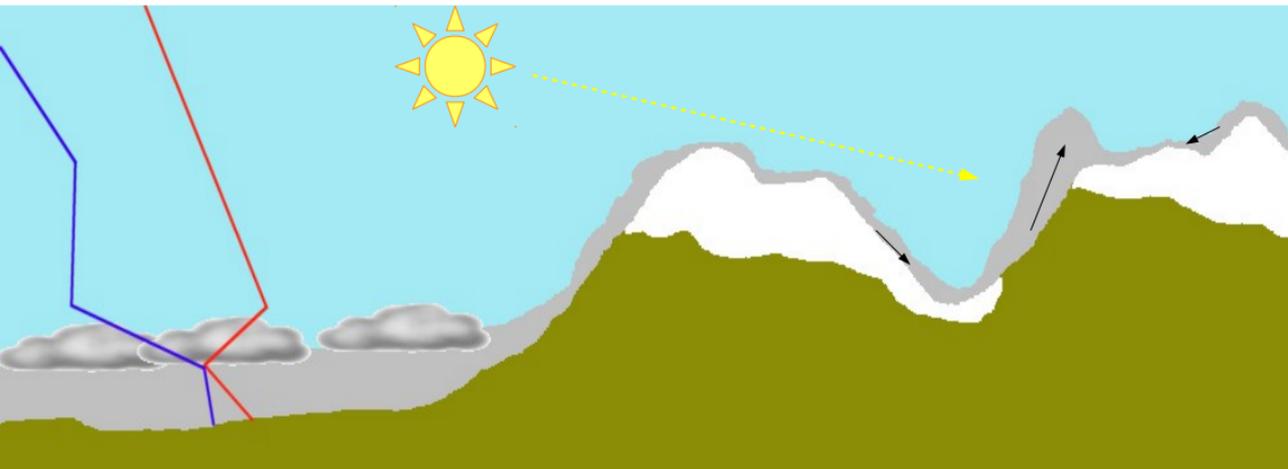
Due to its small volume confined between slopes, air in the valley is warmer than air on adjacent flat lands.

The CBL undergoes the strong valley wind resulting in a cold air advection from the adjacent flat lands and a strong inversion at its top.

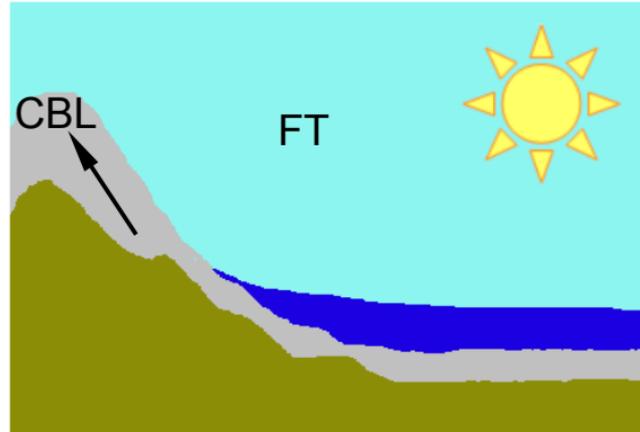
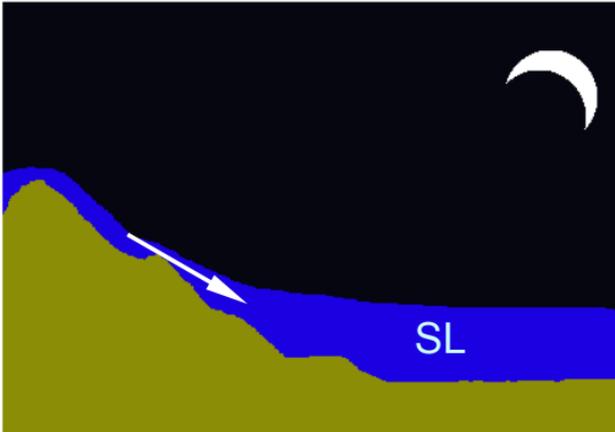
At this low level, the flat land and the valley present often the same temperature.

In winter and fall, the mountainous CBL is often very thin over the icy, snow-covered or often shaded ground (weak solar declination). Locally, over sunny slopes, some small CBL can be interesting for modest thermal soaring games in mountains.

Over the adjacent large and low flat land, the CBL is often thin and wet. It results in low stratus and stratocumulus overdevelopment there.

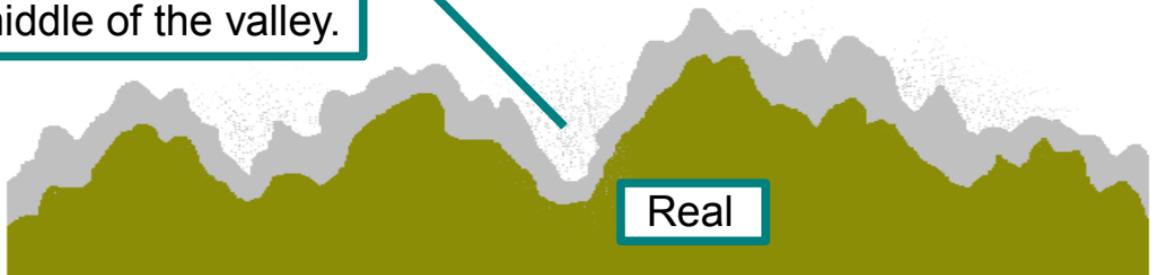
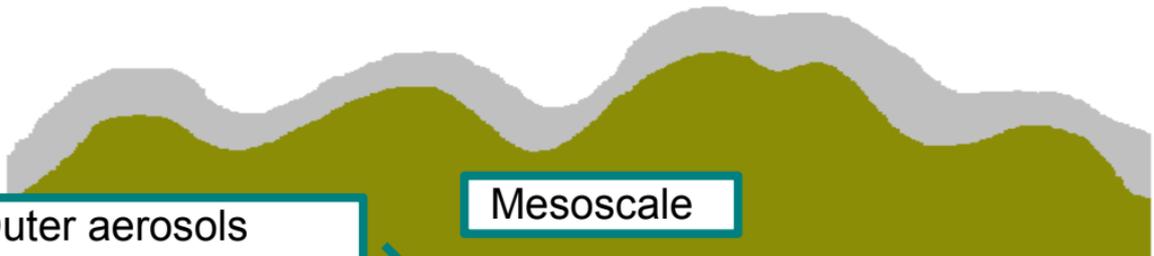


Why thermals appear so early on the eastern high slopes in mountains compared to flat lands ? Probably, the main reason is that the nocturnal stable layer is thin over the high slopes because the cold air, collecting during the night, does not stagnate here but slips downward to the lower parts of the mountain. Accordingly, when the sun rises, this inversion dissipates quickly to leave room for an early deep CBL.

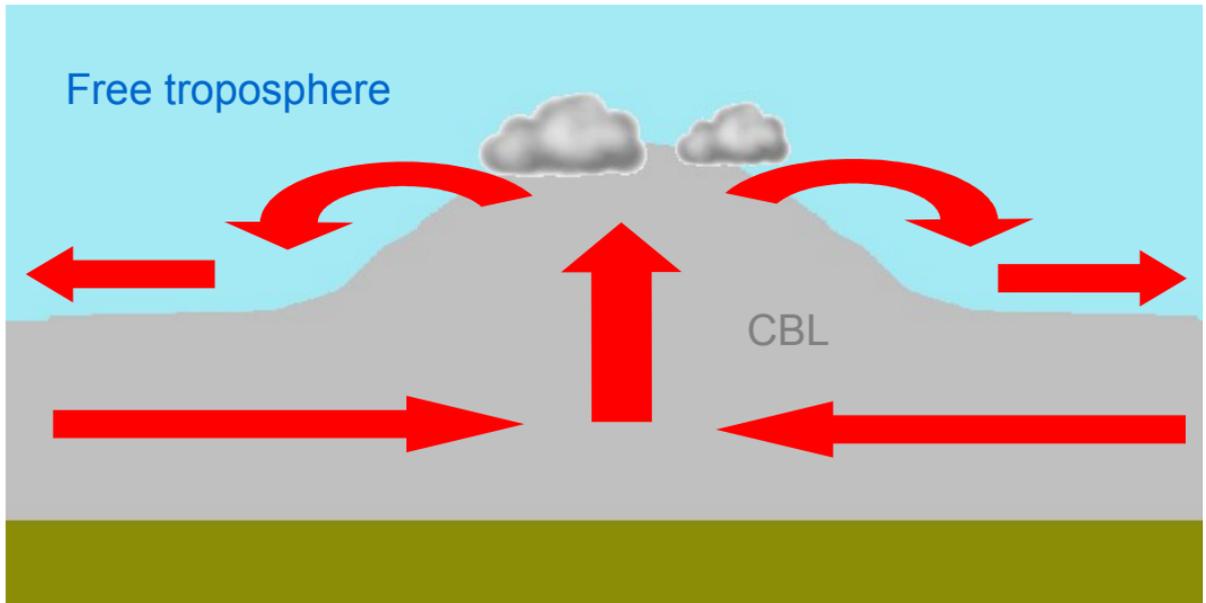


Macroscale, mesoscale and real cross-sectional aspect of topography and CBL in complex terrain :

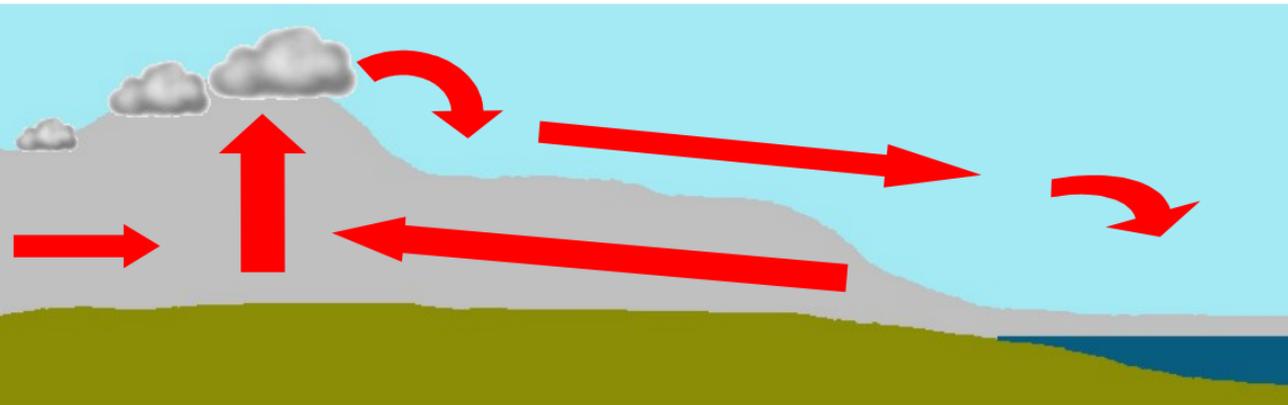
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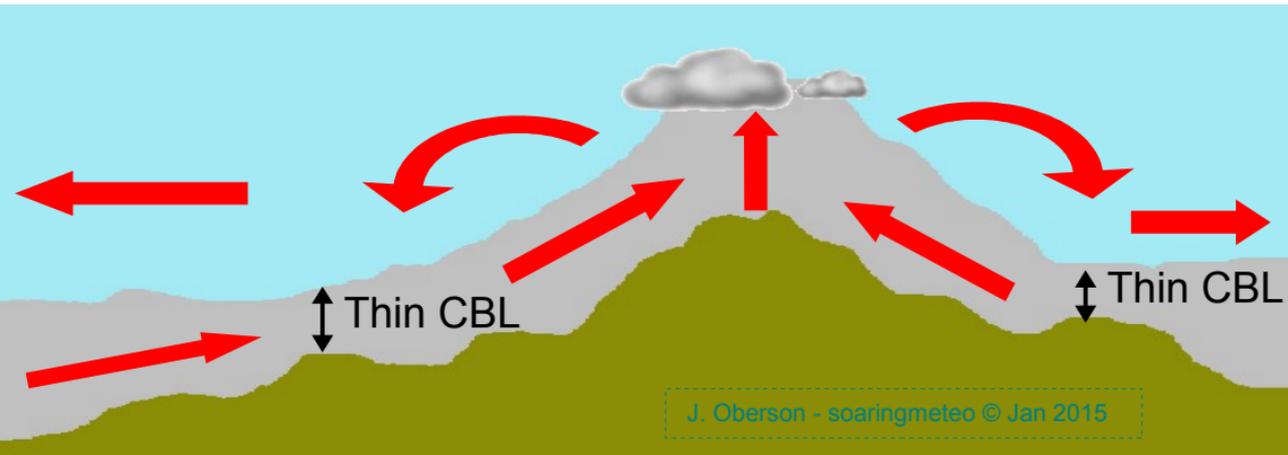
Convergence of opposite airflows results in zonal upward air motion and therefore thickening of CBL with stronger and higher top thermals on this zone. Beside the convergence area, there is some downward air subsidence and then upper opposite outward airflows (divergence).



A first example of convergence results from the opposition of a moderate general wind inside the CBL from the land and a well established sea breeze. The elongated convergence area usually extends along the sea coast, a few to several kilometres from it. If the general opposite wind or the sea breeze are too strong or too weak, this convergence area can be less well established.



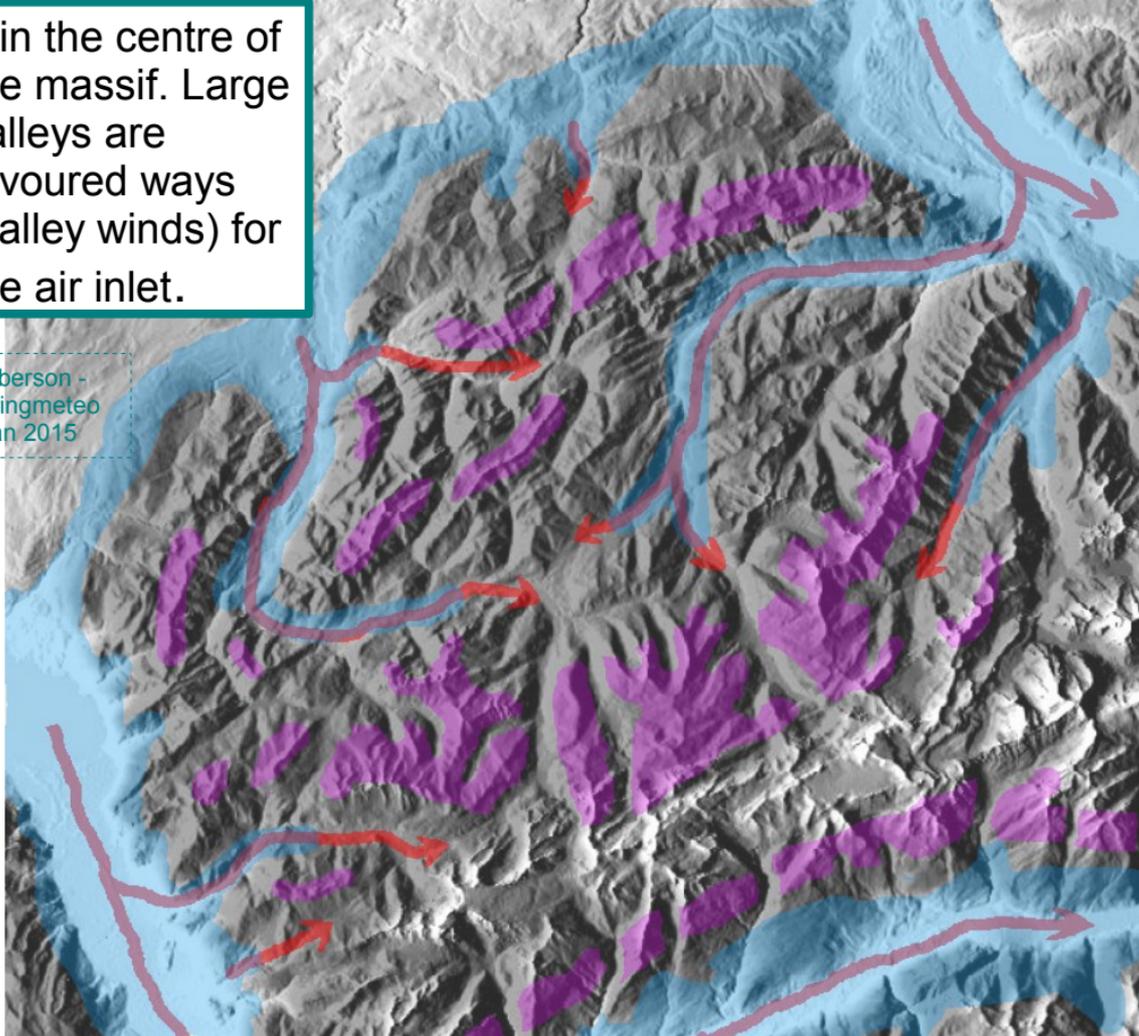
A second example of convergence results from the opposition of two thermal slope breezes from each side of a elongated mountain ridge. On the lower foothills the CBL can be thin, with weak thermals, due to the downward return flow subsidence.



The third and last example of convergence is a very complex one due to the extreme variability of the topography of a mountain massif. There are numerous convergence areas (violet) on the main peaks, especially in the centre of the massif where the CBL is deepest and thermals are strongest. On periphery and in the large deep main valley (blue) the CBL is thin. There is a pumping of air from outside to inside the massif due to a efficient heating...

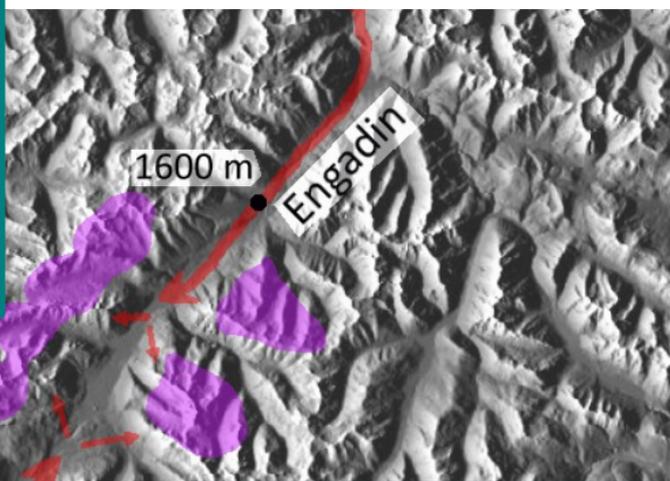
...in the centre of the massif. Large valleys are favoured ways (valley winds) for the air inlet.

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The convergence area is often not located at the highest point (e.g. pass) but on the most heating location instead. It leads to the downward “Maloja wind” phenomena on a short...

...segment at the highest part of the valley in place of the upward valley wind.



The convergence does not occur in the middle of the valley but on the right next lateral mountains rather.

