JANUARY 2014

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WORLDWIDE PARAGLIDING AND PARAMOTORING MAGAZINE. FOR FREE.

ALTITUDES

WHAT HEIGHT ARE YOU REALLY AT?

QNH, QFE, FL, BARO, GPS ...

Photo: Niviuk

Our varios and GPSs tell us, amongst other things, our altitude. But which altitude? For a given position, at least three different readings can be arguably "correct". When it comes to respecting airspace this uncertainty isn't practical.

By Sascha Burkhardt
Translation: Ruth Jessop

Photo: Eki Maute / Ozone

Before the advent of GPSs, everything was a bit simpler. To give altitude our instruments only needed to use barometric measurements, already used by the pioneers of aviation. The problem with this is that atmospheric pressure not only changes with altitude but also in relation to the weather. The difference can be considerable.

In mainland France you can have a range of approximately 950 -1050 hPa. According to Météo France, the French record during the last fifty years was a reading of 1048 hPa in the Loire Atlantique region on the 3rd of March 1990. The lowest ever barometric reading was 951 hPa, on the 25th of February 1989 at the Pointe de la Hague.

Abroad, the lowest value ever recorded was 870 hPa in the centre of a typhoon near the Philippines in October 1979. The highest pressure ever recorded was 1083 hPa in Russia on the 31st of December 1968 at the heart of the famous Siberian winter anticyclone.

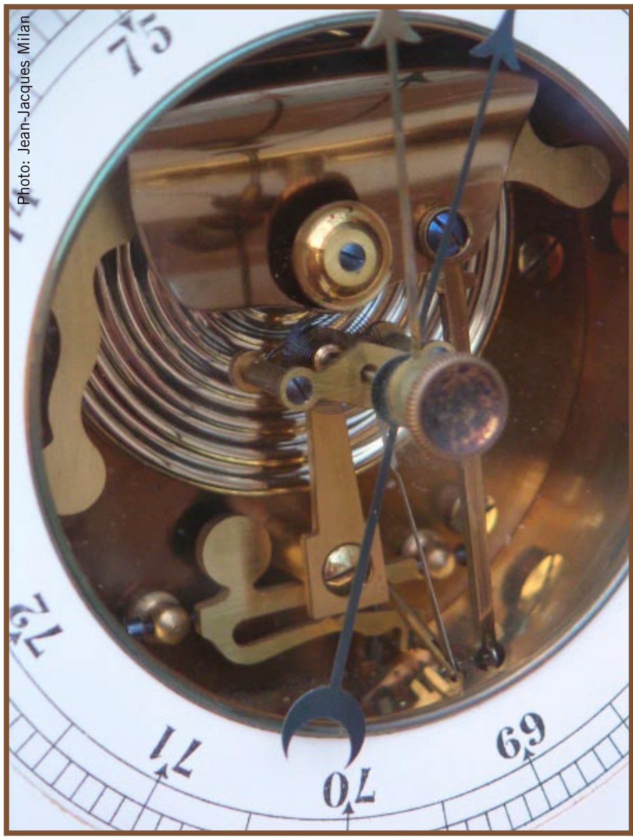


Photo: Jean-Jacques Milan

THE BAROMETER

The principle is well known, they measure air pressure. The higher you are, the less dense the air. Torricelli had already invented the mercury barometer in 1643, less practical to take up into the air than the aneroid barometer.

The latter is composed of a capsule with a vacuum inside whose walls are kept apart by a spring. The atmospheric pressure compresses the capsule a lot or a little depending on the air pressure thus turning a needle on a dial.

By taking this instrument up into the air, the position of the needle indicates the altitude.

At 3000 m, in a standard atmosphere, absolute pressure is only 701 hPa compared to 1013 hPa at sea level.

Even during periods of stable weather, the pressure varies during the day, a bit like tides; the fluid 'air' is subject to the gravitational forces of the stars, with two minima and two maxima during each day. At the Poles the variation is almost zero but at the Tropics, it can reach as much as 4 hPa. In France, this variation is about 1 hPa. For an altimeter, this equals a difference of about 8 – 10 metres.

With the approach of a depression, a barometer can easily drop by 4 hPa in three hours. At the lowest atmospheric levels, a barometer used as an altimeter will show a difference of 40m. This is already a significant error.

Variation with altitude.
In standard atmosphere, pressure variation with respect to altitude is not linear. As you can see in the table, the pressure drops by 114 hPa between sea level and an altitude of 1000 metres, then by 104 hPa between 1000m and 2000 metres.

VARIATION OF PRESSURE IN A STANDARD ATMOSPHERE

ALTITUDE (m)	TEMPERATURE (°C)	PRESSURE (hPa)	REDUCTION IN PRESSURE (HPA) BY 1000 M
0	15	1 013	114
1 000	8,5	899	104
2 000	2	795	94
3 000	-4,5	701	85
4 000	-11	616	76
5 000	-17,5	540	68
6 000	-24	472	62

Altitude is a very important measure when it comes to respecting airspace. Here, even without instruments, there is no doubt about it; the pilot is 'in'… except that on that particular day, the CTR and the TMA were exceptionally inactive.

'In a standard atmosphere, absolute pressure is 795 hPa at 2000m. It is impossible to have the same value at sea level, even in the centre of a hurricane.'

Between 5000 and 6000 meters, the pressure only decreases by 62 hPa. A barometric altimeter needs to take this into account. The readings also vary according to the temperature. Cold air is denser; the value of the variation will change equally.

How does this affect us?

For the paraglider or paramotor pilot, the possible variations, in particular due to the weather, can quite easily cause problems near airspace, especially during competitions. The violation of a restricted zone can cost 10 points per metre, in other words 500 points for 50 metres. Nonetheless, it is rare for pilots to calibrate their altimeter at the take off. Sometimes the organizers don't even announce the exact altitude of the take off.

For larger aircraft it is however an obvious measurement to know. At airfields the control tower or the ATIS broadcasts give the actual pressure as well as the QNH and the QFE. Before take off, the pilots calibrate their altimeters according to these pressures. Calibrated according to QNH, the altimeter will then show the exact altitude of the airport, calibrated according to QFE, the altimeter will read zero on the tarmac.

"At a flying site, dozens of kilometres from an airport, the pressure given by ATIS is perfectly usable".

Amongst the instruments for paragliding, some allow the user to calibrate the altitude via QNH. At the foot (or the summit) of a site dozens of kilometres from an airport, the pressure given by the airport is still perfectly usable, the variation in pressure is normally very small over a distance of up to 50 - 100km.

GPS altitudes: good for absolute, bad for differences.

The arrival of the GPS not only revolutionized our ability to pinpoint two dimensional positions on maps, but it also gave us an additional way to work out our altitude. The advantage of the GPS is that it doesn't depend (well almost) on the weather, it displays a precise location, which is virtually always at the same altitude, whether in a wide anticyclone or in a monster depression.

The downside of a GPS is that when you switch it on, the reading isn't always that accurate and may be wrong by tens or hundreds of metres, it needs time to find sufficient satellites positioned in a favourable geometry. After that, the altitude is relatively precise, even though, from time to time, errors of up to twenty meters do occur.

Photo: Jody MacDonald

The other big draw back of GPS altitude readings is that they aren't really usable for measuring differences in height. A vario equipped with a barometric sensor starts to beep as soon as you have gone up several centimetres, it is easy to demonstrate if you lift it up while stationary. With a GPS, that isn't possible.

All the efforts to use a GPS as a variometer have failed miserably. The numerous apps for iPhone or Android which try to simulate a variometer based on the GPS chip are not really usable. In straight flight, these applications sometimes show lift of +10 m/s – all that needs to happen is for the instrument to fix onto another satellite to cause this type of error. Conversely, a real height gain in a thermal generally appears on the screen too late, by which time the pilot has already lost the lift. The only workable solution is to use a real barometric sensor, either by integrating it into the smartphone or by linking the latter to an external module like the Flynet.

The numerous apps for iPhone or Android simulating variometers using only the GPS chip are not really usable.

With the arrival of a depression, the barometric altitude reading can easily vary by 20-40 metres.

Photo: Niviuk

Photos: Sascha Burkhardt

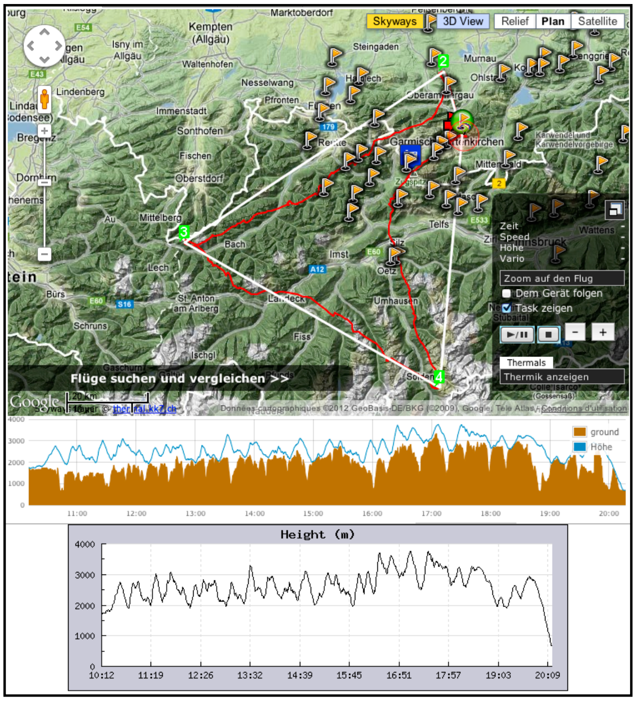
The altitude A1 indicated on a Flytec/Bräuniger next to the dial (here, 1594m) is always based on the barometric measurement. The altitude in feet (here 5229ft) represents the same value recalculated by the system used in aviation. But it still isn't an FL altitude, even after taking off the last two digits. The flight level (FL) that this instrument can equally show is calculated by using a standard pressure of 1013.25 hPa, regardless of what the real pressure is that day.

On the older Favorit made by Aircotec, the button on the right allows you to choose between A1, A2 and FL altitude (QNE).

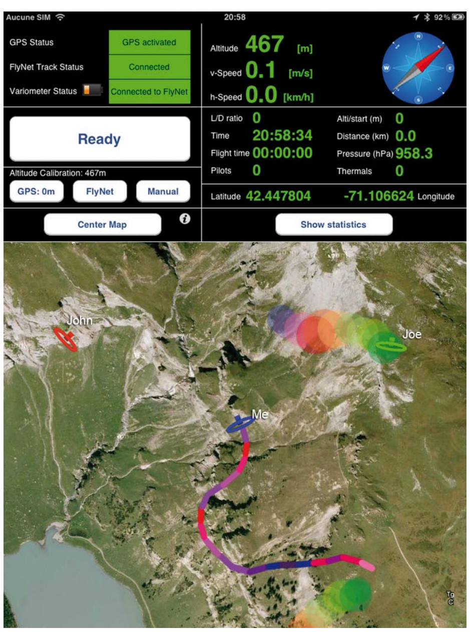
In reality

Most instruments with integrated GPS can display either the barometric altitude, the GPS altitude or both. To calibrate the barometric altimeter to the day's pressure, the instruments adopt different strategies. Most instruments, like the VGP made by Reversale, look for satellites as soon as they are switched on, and as soon as they get a reliable fix, the barometric altimeter is calibrated to this value. With Flytec and Bräuniger, the varios not only wait to get an exact value but continue to observe the GPS altitude right up until take off at which point they calibrate themselves definitively. (Take off is recognized by significant changes in ground speed or by the variometer). The instrument has thus had time to acquire properly so that, once airborne, it gives a more accurate measurement of the altitude of the take off. From then on and throughout the flight, the instrument only uses barometric values to show the barometric altitude; a recalibration isn't necessary. At take off the Skytraxx 2.0 uses a completely different strategy to calibrate the barometric altitude. The instrument has a database of European topography. For all the points in a horizontal grid 90m x 90m, the database contains the ground-level altitudes. The main reason for this is to give a pilot whilst in the air the AGL, i.e. the precise height above the ground beneath his feet.

With the increase in distance flights being declared on the internet on sites like www.xcontest.org, respecting airspace, which is easy to check, is paramount.



In neighbouring countries, declarations on distance record sites have become so important that pilots try to cheat by flying through airspace. This flight however seems "clean".



The altitude in the application Flynet (which can be used on an iPhone, iPad or Android, linked to the instrument of the same name from ASI) corresponds to the barometric altitude transmitted by the module. Before take off, the pilot can calibrate it either on the GPS on the iPhone or by using a height from the topography, or manually.

The Skytraxx 2.0 uses the same information to calibrate its altimeter at the take off. As the altitude measured by the GPS, just after it is switched on, isn't very precise in contrast to its 2D position, the Skytraxx reads the altitude of the ground from its database and calibrates its barometric altimeter on that basis. Clever. By request, the application Flynet from ASI does the same to calibrate the barometric value received from the module via blue tooth. In contrast to Skytraxx, the app takes the altitude from the topographic model not from internal memory, but on-line from the constructor's database server. These systems work very well in most cases, except possibly for a cliff top take off, if the instrument takes from the database the altitude of a point, for example, 40 metres in front of the take off.

In flight

If the instrument has been able to calibrate itself correctly at take off, there shouldn't be a significant difference between the GPS altitude and the barometric altitude throughout the flight. For most instruments 'don't touch the barometer' applies, but there are some exceptions.

The Flynet connects via Blue tooth to an iPhone or an iPad as well as to a smartphone or an Android tablet. This instrument provides a very precise air pressure sensor for these mini computers.

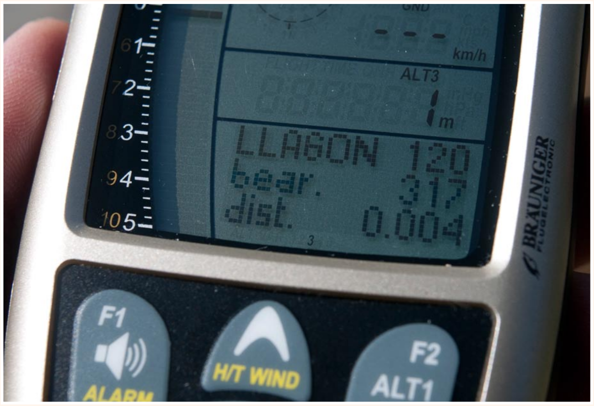
The Sys GPS made by Syride regularly checks the difference between the barometric altitude and that calculated by the GPS. If the difference is too big, it recalibrates the barometer on a 'good' GPS value.

Tracklogs and IGC files. Is stopping the cheats a top priority?

It isn't necessarily the case that the user needs to know what altitude appears on his instrument screen, especially for instruments which give a choice of display. Yet, to be warned about a possible violation of airspace, by being too high or too low, isn't just important in a competition, but also for distance flying, especially if the flight is going to be declared on a website like the XC distance competition XContest (www.xcontest.org). Because these websites can be designed to automatically detect tracklogs which 'cross the red line'. At the moment this isn't the case on all XC websites, but thanks to downloadable IGC tracklogs, any internet surfer can check the competitor's tracklogs. But even on the tracklogs produced by the instrument,

Measuring altitude always depends on what reference has been used. Here the pilots are at 30m above the ground, 3810 m above Chamonix and 4840 m above sea level.
It is worth noting that according to IGN's most recent measurements in the summer of 2013, Mont-Blanc is 4810.02 metres high, having lost 42 centimetres since 2011.

Photo: Jérôme Maupoint



On the Flytec/Bräuniger, altitude 3 is automatically reset to zero when the pilot takes off, so that it shows the height gain relative to launch. The measurement is based on the air pressure sensor.

Before take off, the pilot can decide if the VGP should calibrate its barometric altimeter according to the GPS or not.

On the excellent GPS watch, the Ambit 1, made by SUUNTO, a small point: the barometric altitude can't be easily calibrated from the GPS.

As is the case for most instruments, there is nothing to indicate on the screen of this Flymaster whether the three altitudes come from the GPS or the barometer.

As is the case for all instruments, if the pilot has doubts about the automatic calibration of the barometric altimeter, he can obviously enter the altitude of the take off manually.

Photos: Sascha Burkhardt

The altitude, combined with the climb rate and the ground speed are very useful pieces of information. The main screen on the Syride Sys'GPS displays it in a very readable fashion.

there isn't necessarily the same type of altitude.
The XC Trainer made by Aircotec only records barometric altitude.
The Skytraxx 1 does the same, but the Skytraxx 2.0 onwards records the GPS altitude and the barometric altitude. This is also the case with the Flymaster and with the Flytec/Bräuniger.
One thing all the instruments have in common is that to stick as close as possible to the IGC requirements, the barometric value kept in the tracklogs completely ignores any manual calibration made that day by the pilot or automatically by the GPS. The instrument acts as if the pressure for the day was 1013 hPa at sea level and writes QNE altitudes corresponding to measured pressures in its memory.

Consequently, the user can't calibrate his instrument on made up figures to cut corners with respect to airspace. During a check, the competition officials could recalculate the real altitudes by taking into account the regional pressure that day, a value that can be easily obtained from weather forecast records.
In France, the spirit of the CFD (Coupe Fédérale de Distance) fortunately has not yet been poisoned by this level of suspicion – in other countries, the phenomenon of on line distance competitions has become so important that, despite there being no financial prizes linked to the various categories, some pilots knowingly cheat and don't hesitate to switch off their GPSs before crossing forbidden zones.

Instruments like the Skytraxx 2.0 or the Syride Sys'GPS have a regional or national database with the relief heights. If required it can display an AGL altitude, i.e. the height above the ground. Worth noting, the database resolution is 90 metres. As you fly over one of these outcrops with vertical walls, the instrument can continue to temporarily indicate height above the sea.

Flytec
KING OF THE AIR

The new Flytec 7030 with Sun Readable Display.

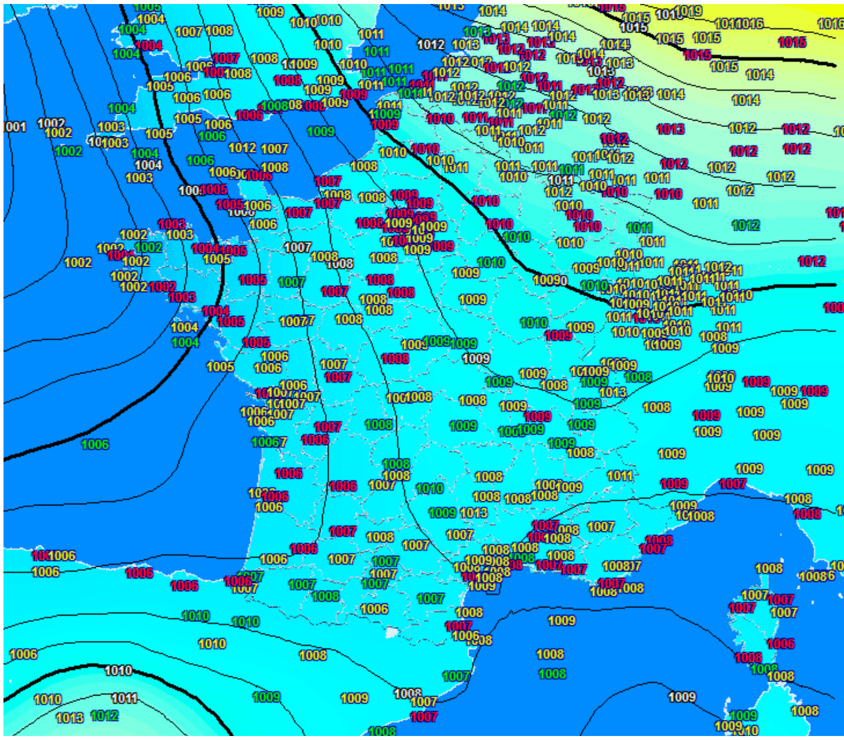
The new Flytec 7030, with "Glove Touch" greyscale display, remains perfectly readable in direct sunlight and is fully functional with gloves on. The 7030 features international road, aeronautical and topographical maps, thermal assistant with ultra-sensitive variometer, advanced flight sensors, and Bluetooth 4.0 LE for easy connection to smart phones, tablets, Google Glass™ and live tracking.

flytec.ch

Photo: Sascha Burkhardt

One flight deck, three instruments, five altitudes, initially before calibration. The differences can be phenomenal according to their settings, yet each of these instruments is precise.

The rules allow holes in their tracklogs of up to fifteen minutes in the flight recording.
It is therefore ‘by chance’ that the GPS doesn’t work next to a CTR…
Therein lies another problem for competition organisers. It is perfectly acceptable to use a simple GPS without a barometric altimeter and the competitors using this sort of instrument submit tracklogs in which the altitudes differ from those registered by dedicated flight instruments. Just to make the confusion perfect, certain Garmin GPSs have a barometric air pressure sensor which registers values based on a mathematical fusion of barometric and GPS altitudes using a ‘Kalman filtering’ algorithm.



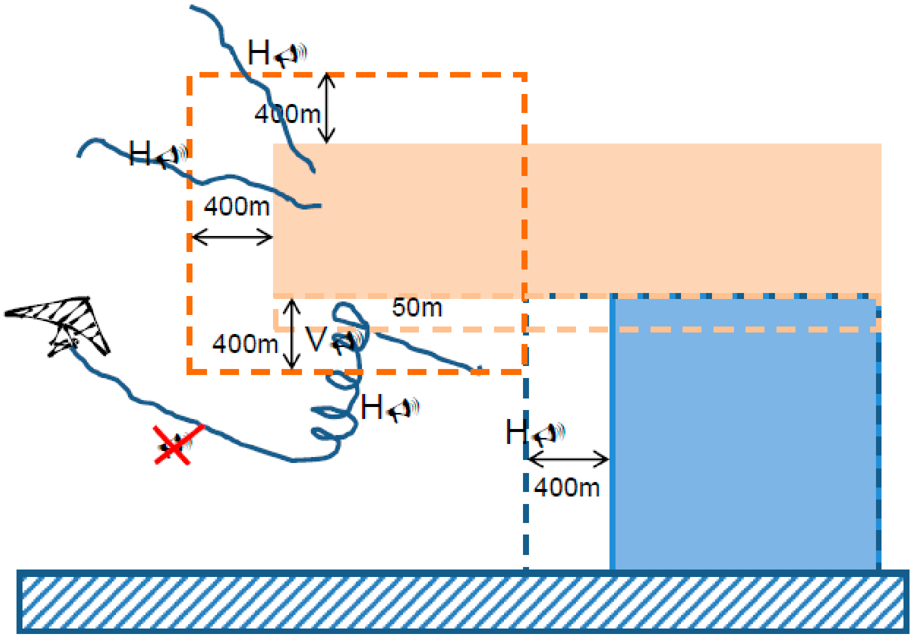
On the web, the service Meteociel shows on its page ‘Pressions’ (http://www.meteociel.fr/accueil/pression.php) a map which is much more informative than a simple isobar map. This brings together the pressure readings transmitted by numerous weather stations in France in more or less real time. Among other things, one can see that the variations are relatively small at a regional level.

Photo: Karen Skinner/Niviuk

FL - Flight Level

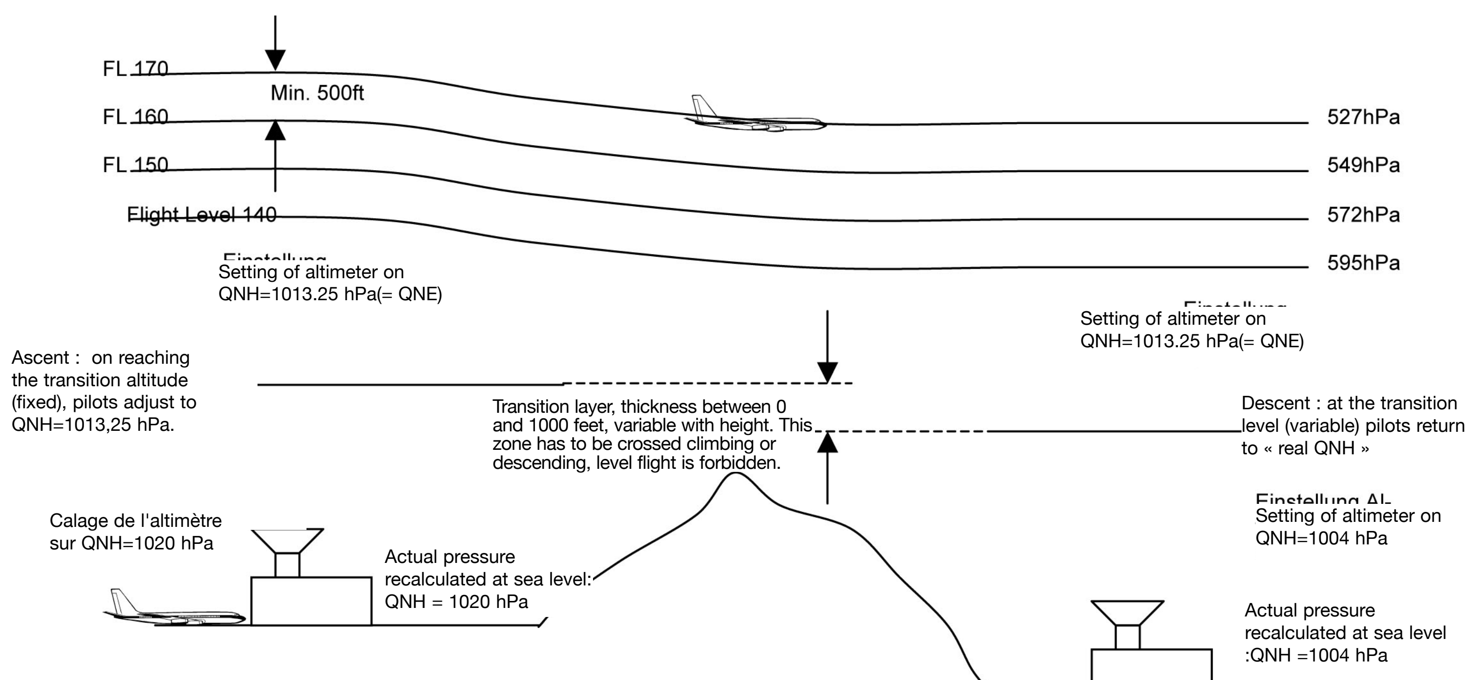
The difference between barometric and GPS values become a lot more important when we have to share airspace, expressed in Flight Level, with light to very much heavier aircraft. FL 55, for example, corresponds to an altitude of 5500 feet; it appears therefore all that needs to be done is to simply add two zeros to the end to get the height in feet. To convert this figure to metres, multiply by 0.3048 (1 metre = 3.281 feet, 1 foot = 0.3048 metres), and we get 1676 metres. But it isn't as simple as that. FL isn't based on an altitude that one can measure by GPS, but by an altimeter that pilots calibrate based on 1013 hPa, irrespective of whether that is in the centre of a depression or under an anticyclone. As with the IGC tracklog, the instrument acts as if the pressure that day is 'standard', and gives an altitude which doesn't correspond with the real height of the relief, except on days where the pressure at sea level is really 1013,25 hPa.

On Flytec instruments, it is possible to alter the margin within which an 'airspace warning' will be given. The distance chosen here is 400 metres, correct for a horizontal approach as well as a vertical approach.

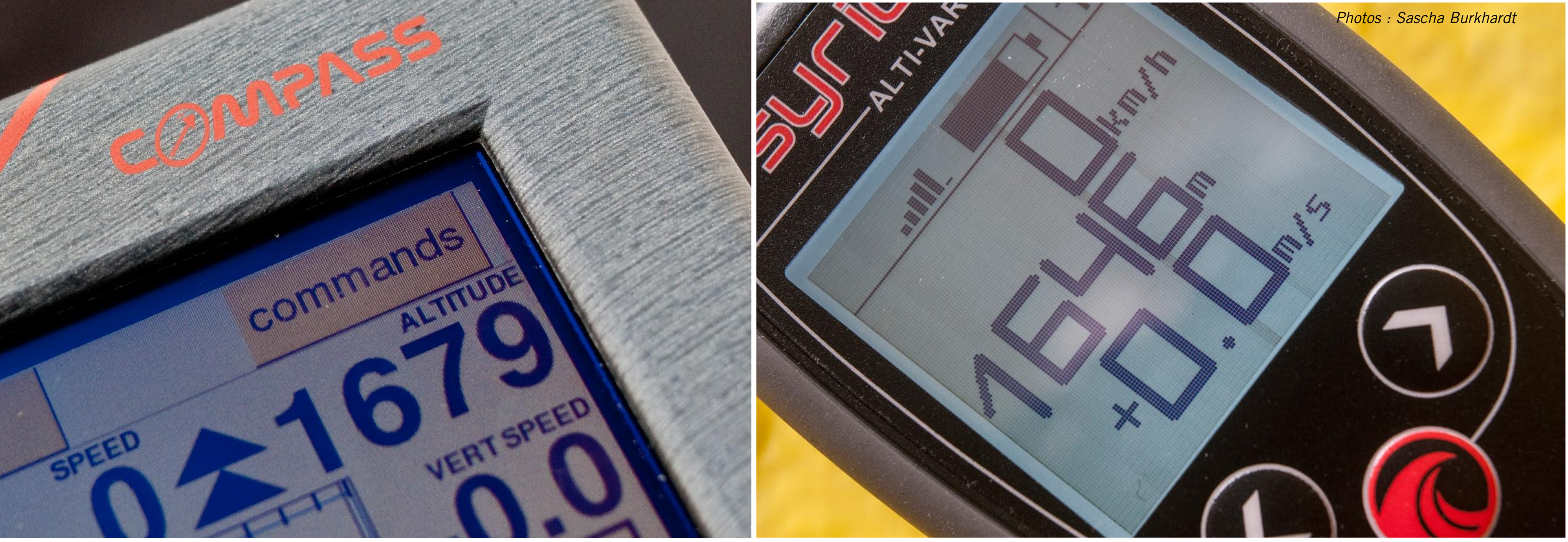


The reason for this 'systematic and necessary error', is that for example when a plane flies from Paris to Palerme, it may pass by regions where the pressure is a lot lower or higher than it was at its departure point. To know the precise height above sea level, one needs to constantly recalibrate the altimeter according to local pressure in the regions the plane flies over.
That isn't practical, and there would be the possibility of colliding with other planes whose altimeter was calibrated differently. At cruising altitude what really matters is not so much to know if the plane is at 4000 metres or at 4100 metres above a mountain, but above all to maintain separation between traffic.

VFR flights use flight levels ending in a 5, like FL 45 or FL 55, IFR flights use flight levels ending in a 0 (FL 50, FL 60). The traffic is equally separated according to the magnetic track, so for example for VFR: Track between 180° – 359°, FL 45, FL 65, FL 85. Track between 0° – 179°, FL 55, FL 75, FL 95. Thanks to these rules, a distance of 1000 feet is assured between two aircraft following the same flight path in opposite directions.



Real altitudes of flight levels change with atmospheric pressure. Here, a depression close to the sea reduces the barometric value the other side of the Alps. On following correctly a flight level, planes fly lower and lower as they approach their destination. As the «error » is the same for everyone, the separation of air traffic stays assured….
Diagram : Erich Lerch/Flytec



Photos : Sascha Burkhardt

Barometric or GPS? Nothing shows what the instrument uses. A particularity of the Syride Sys'GPS on the right is that the altitude displayed is principally barometric, but if during a flight the instrument detects too big a difference between the GPS and the barometric readings, it readjusts the barometric readings. Most instruments on the market, after take off, won't let the user recalibrate them.

As everyone has calibrated their altimeter according to the same barometric value, everyone flies with the same error, a minimum distance between everyone is therefore guaranteed. Before landing at an airport, it is obviously necessary to recalibrate the barometer according to the pressure in that particular location, thus giving the remaining height and allowing the pilot to respect height/ground regulations.
The change from an FL calibration to a normal calibration is done at the point in the plane's descent when it reaches the transition level expressed in FL. This value, for example 50, is communicated by the controller and the ATIS. Flying above 2000 metres above sea level, a pilot will generally be in layers where "the others" fly in FL.

Airspace of variable size
Flight level issues may not appear to be something that preoccupies us. But in certain paragliding competitions, flight levels have already caused problems in the tracklogs.
Because the height of the flight level above the sea and above the relief changes as a function of the barometric pressure on the day, therefore, it is exactly the same for the height of airspace whose limits are expressed in FL !

Pilots flying only with a GPS could easily find themselves in airspace whose limits have shifted.

THE PARA WORDS

Glossary

AGL :
Above Ground Level, height above the ground. To obtain this the instrument needs to know its position and the topography of the land it is flying over.

AMSL :
Above Mean Sea Level, altitude in relation to the sea.

ATIS :
Automatic Terminal Information Service, an automatic service which continuously broadcasts information like the pressure on the runways currently being used. Also useful for calibrating an altimeter at a nearby flying site. http://en.wikipedia.org/wiki/Automatic_Terminal_Information_Service

QNH :
Pressure at sea level. It gives the absolute altitude above sea level, read on an altimeter calibrated according to this actual pressure, correct at the point where the pilot is, and recalculated in relation to sea level. On the ground, the altimeter therefore shows the height of the airport above the sea.

QFE :
Pressure at a given place. It gives the height with respect to a given point, read on an altimeter calibrated to this actual pressure. The altimeter therefore shows 0 on the ground.

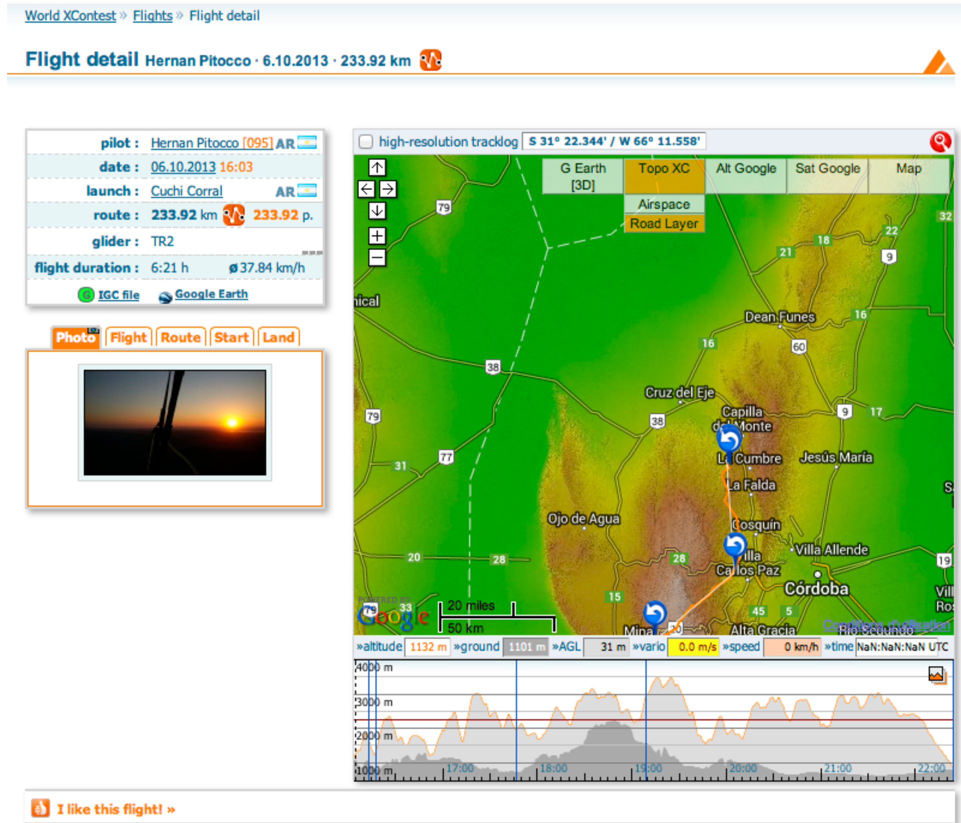
QNE :
The value shown by an altimeter calibrated according to standard atmosphere (1013.25 hPa), plane on the ground, whatever the real pressure is at the time. The levels FL (Flight Level) equally represent QNE altitudes.

SUMMARY

Clearly, it isn't obvious how to measure altitude in a precise way. In addition, there are different ways to express our height and there are inaccuracies due to the methods used to make the measurements. We haven't even touched upon the errors which are subject to barometric measures which are affected by the temperature – if the latter is far from the value of standard atmosphere (anticyclone giving hot air, depression giving cold air), the measurement can differ by up to 100 metres.

In practice, if we fly in regions where the airspace limits are expressed in FL even at low altitude (around Salève for example), it could be useful to display the FL altitudes in a field in the instrument if it has this facility.

In other places, if we display barometric altitude in relation to the ground or GPS altitude, we need to bear in mind that the vertical margins with respect to the airspace must remain a lot bigger than the horizontal margins. ■



Like most instruments, at take off, the Ascent calibrates its barometric altimeter from the GPS. The altitude displayed during the flight remains close to the real height above sea level except for when there is a significant change in the weather.

In Hernan Pitocco's recent flight declared on the website XContest, one can see the difference between the two altitudes recorded by the IGC tracklog. In the blue column the barometric altitude, based on a pressure of 1013 hPa, in the yellow column, GPS altitude is used. This last column is naturally more realistic: At launch it was at 1132m. In reality the take off was at 1101m ('ground' on the topology database).
The barometric altitude registered was 1011m, 100m lower – it would only be close to the GPS altitude on a day when the pressure was 1013 hPa at sea level.
Obviously, for the rest of the flight, a difference between the two measurements would remain, but the difference isn't constant due to inaccuracies in the way the GPS measures altitude. .

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AXGD Flymaster F1, V1.21, S/N 2682
HFDTE061013
HOPLTPILOT: Hernan Pitocco
HOGTYGLIDERTYPE: Open class
HOGIDGLIDERID:
HODTM100GPSDATUM: WGS-84
HOCIDCOMPETITIONID:
HOCCLCOMPETITION CLASS:
HOSITSite:
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Flying over the sea, a unique moment in many respects; for once, the altitude is the same as the height.

Photo : Karen Skinner/Niviuk


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