How High am I?

A competitors guide for not zeroing the day …..

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The title isn't a question from the 60's, but rather a reaction to last year's Brasilia Cat 1 test event where ten pilots violated the vertical airspace limits and were zeroed for the day. In talking to a sampling of pilots, it became clear that there was some confusion about how the whole altitude/scoring thing worked, how accurate our instruments are and what the errors in the system may be. That's understandable, as many pilots don't often deal with controlled airspaces in their local flying, but it is becoming increasingly common in competitions.

For those competition pilots that don't want to wade through all the technical info below, here is the short story. Set your instrument to the proper launch altitude each day before you fly, give yourself a 100 foot buffer to the penalty altitude and you are good to go! For those that want to get closer to the limit, we need to talk about QNH, International Standard Atmosphere (ISA), Flight Level (FL), QNE and instrument bias error to better understand just what the heck these terms are and how they relate to our instrument altitude errors, with the goal of learning what we can do to minimize these errors (i.e. not get a zero for the day!).

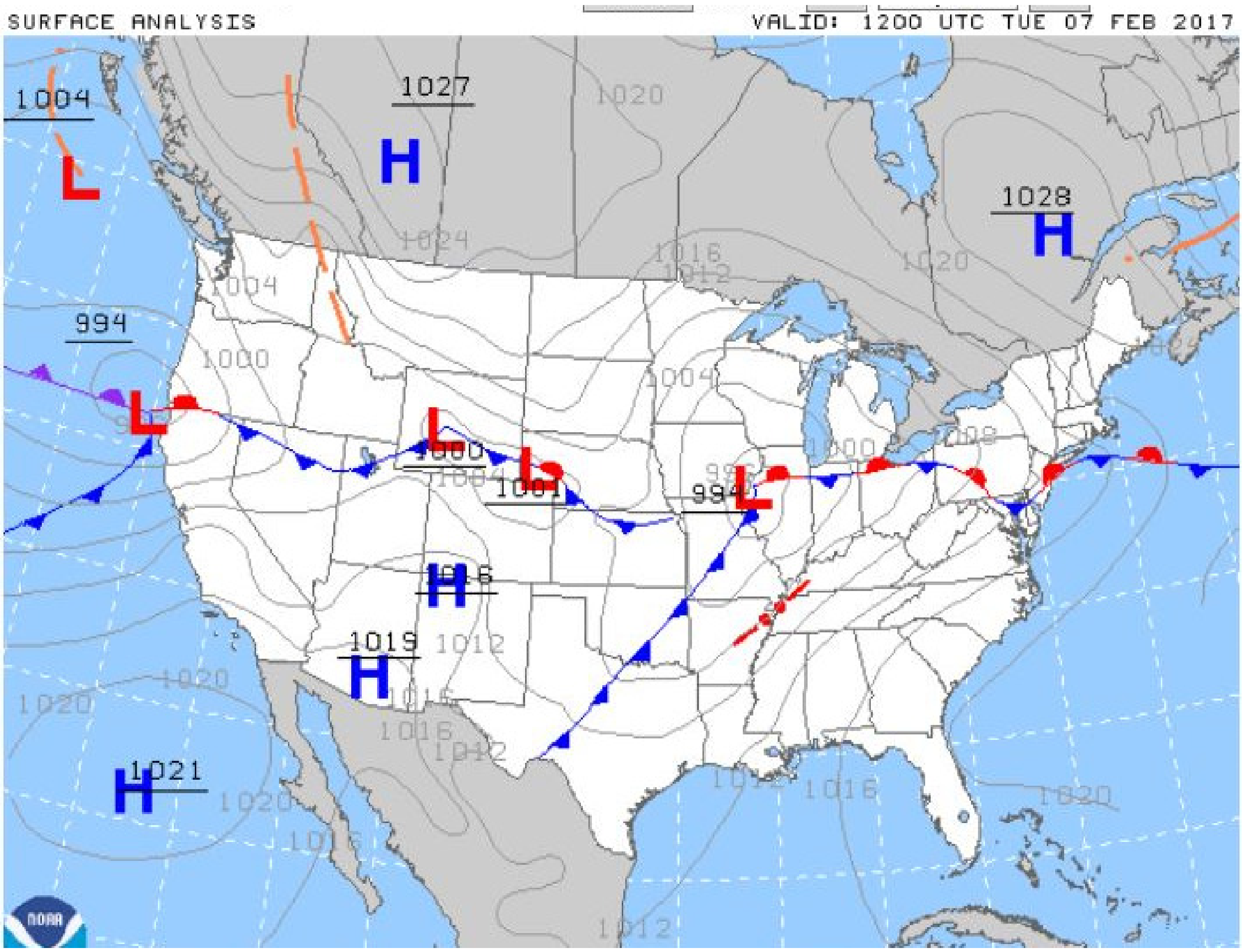
All pilots have a general understanding about how barometric pressure altimeters work to tell how high we are. It is truly amazing how these little instruments can detect the tiny pressure changes of just a few feet and do it so well. This sensitivity may give you the impression that they can very accurately tell how high you are, but that is only true if the instrument is setup each day properly and even then, it may be tens of meters off for reasons we will discuss below. When those tens of meters are the difference between getting your score or a zero for the day, it's worth taking the time to understand a bit more about what's involved.

The first major effect to understand (and most pilots do) is that the pressure we fly in changes with the weather. High pressure systems make our favorite launch altitudes read lower and low pressure systems the opposite. Because of these pressure changes, most pilots adjust their instrument's main altitude display (typically called A1) to read the established Mean Sea Level (MSL) altitude of launch. This does a good enough job for most circumstances to get the A1 accuracy required for the flight.

QNH

What adjusting A1 does in our instruments is adjust the QNH pressure term. QNH is a Q code (see https://en.wikipedia.org/wiki/Q_code) for the barometric pressure under the current weather conditions adjusted to sea level (see https://en.wikipedia.org/wiki/Flight_level#Transition_altitude). Using QNH, the instrument calculates (using a formula most probably don't want to see, but you can go here if you want to https://en.wikipedia.org/wiki/Atmospheric_pressure) the MSL altitude based on the barometric pressure the instruments pressure sensor measures.

You can look at the isobars numbers on the US national weather map below to get a feel on the magnitude of the pressure changes between the typical high and low pressure areas shown. There is around 20-30 millibar (mb) difference between the high and low pressure systems. Of more interest to us is the 5-10 mb difference between the high pressure systems, as we typically don't fly around in the low pressure systems. With a one mb pressure change being equivalent to about 8 meters, not adjusting your A1 for the current pressure of the day (or doing it improperly) can easily result in errors in the 50-100 meter range. Note that the isobar numbers shown are not the pressures measured at the location, but rather the measured pressures adjusted by the formula mentioned above to the equivalent pressures that would exist under the current weather conditions at zero MSL – which you might suspect by now is the QNH for that location!



ISA

Now let's talk about the International Standard Atmosphere (ISA), probably the easiest term to understand and the shortest conversation. The QNH discussion made clear that we know our atmosphere changes with the weather patterns. To have a common starting point with which to talk about our changing atmosphere, the ISA is the agreed to "average weather condition" atmosphere (see https://en.wikipedia.org/wiki/International_Standard_Atmo for more). If you have an ISA weather day, the atmospheric pressure at zero MSL (the QNH) is 1013.25 millibars (mb). As you may have already noticed, the weather map above shows high pressure areas with QNHs above 1013.25

mb and low pressure areas less. Based on the defined ISA, 1013.25 mb is the QNH dividing line between high and low pressure systems and is also a common ground (or rather weather) that allows us to define our next term.

FL and QNE

From the QNH discussion above, it is clear that in order to have all pilots flying around with the same MSL reference altitudes (and know how high they are over the terrain below!) each has to be reset their QNH as they travel around. As the concern over terrain clearance goes down (i.e. we get really high) and the flight distances get very long, it makes more sense to fly by Flight Levels (FL). FLs are what the altimeter reads when you set the reference pressure (QNH) to the ISA of 1013.25 mb. What is good about this is it is easy (no resetting the altimeter as you fly along) and everyone is flying with the same reference altimeter setting, which makes vertical separation schemes more effective. Flying by FL is done by aircraft flying above what is called the transition altitude, which is typically in the 10K to 18K foot MSL range and is where most commercial airline flights spend most of their time.

The bad thing about flying by FL is you don't know how high you are above the ground unless somebody tells you more info. That is where QNE comes in. QNE is also Q code that sounds kind of close to QNH, but they are a quite different! QNH is a <u>pressure term value</u> (i.e. 1023 mb) that pilots set their altimeters to and that changes day to day and from place to place depending on weather. QNE, however, is the <u>pressure altitude of an airport runway</u> (i.e. 1534 meters) your A1 would read if you set QNH to the ISA value of 1013.25 mb on your altimeter (i.e. flying by FL). Note that the QNE value (the pressure altitude of the runway) changes with weather conditions.

Although the above is the precise definition of QNE, it is more often used to talk about any pressure altitude determined by setting the altimeters QNH term to 1013.25 mb. So being a little lose with the definition, QNE is the pressure altitude used in flying by Flight Level (FL) and is what most all our flight instruments record in the IGC file format track log for pressure altitude. This last point is why it is worth having in this discussion. The IGC file format specification requires the QNE pressure altitude to be recorded because this provides "the level playing field" from which QNH can then be used to adjust the altitude calculations for the variable weather conditions of each task. It would be much harder to evaluate track log pressure altitudes if what was recorded was everyone's properly (or improperly) QNH adjusted A1 pressure altitudes. The way your altitude is evaluated for possible airspace violations is by correcting the QNE pressure altitude recorded in the IGC file format track log for the QNH pressure of the flying day, unless of course if the airspaces are defined by FLs.

OK, so now you have the reasons our comp rules require the task board to have both the MSL altitude of launch and the QNH for the day that will be used by the scorekeeper to evaluate each pilot's track log. See Sporting Code Section 7A Edition 2016 section 6.3.2 Altitude Verification (available here http://www.fai.org/civl-documents) for the current task board requirements and know that these words will become even more specific when recent changes agreed to in February 2017 become effective in May 2017. With this task board information, you can properly set A1 at launch and, if you have followed all the discussion above, get a feel for your instrument's bias error and/or validate the bias error you measured.

Instrument Bias Error

With QNH, ISA, FL and QNE defined (are you still with me?) it is time to talk about instrument bias error. This is an effect very few pilots I know either determine or take into consideration. While our instruments are crazy accurate and exceptionally linear at measuring relative altitude changes (i.e. I've gone up ten feet), the absolute accuracy of the pressure sensor often have a calibration error (a high or low bias), which can drift over time as the instrument gets older and banged around. A recent survey of the instruments in a competition showed these errors to be in the +/- 20-ish meter range. That said, the error should not change quickly over time (unless you are really hard on your equipment) and its relatively straightforward to figure out what your instrument error is.

On a low wind, high pressure day (i.e. the pressure is the same over a wide area) call (or even better, go to) a local airport or google the local weather resources and get the QNH for the day. Set (or least display) that QNH in your instrument at a place where you precisely know the MSL altitude (again, going to an airport is nice for this). You can then get your instruments error offset for both the QNH bias in mb or the altitude bias in meters or in feet. The pictures below show you how this looks on a 6030 at an airport reporting station. Setting the precise QNH (at this station, QNH was in inches of mercury (inHg) and is on the top left of the reporting station display) and comparing the resulting A1 altimeter reading to the known altitude (7523 ft MSL in this case, as shown on the bottom right of the reporting station display) gives the bias error in feet (27 feet low for the 6030 pictured). Setting A1 to the precise altitude gives you the QNH bias error (0.03 inHg high for the 6030 pictured). The astute will figure out that 0.01 inHg equates to about 10 feet of altitude change.

Figure 1: Instrument set to precise QNH altitude

Figure 2: Instrument set to precise field

Known Bias Error – What to Do?

I'd like to tell you it is a simple matter to understand how to deal with your instrument bias error, but I'm afraid it is not. Consider the case of an instrument with a pressure sensor that has a low bias error. A low reading pressure sensor results in the instrument reporting a higher altitude, both in the recorded QNE and the QNH adjusted A1 if QNH is set to the accurate QNH for the day. In this low bias error case, if you set the correct QNH, you would notice that your A1 would be reading a bit higher than the actual launch MSL elevation. Noticing this, you could then set the correct launch MSL elevation by setting your QNH a bit low. If during the subsequent flight you fly right to the altitude limit based on your A1 reading (with all the other comp pilots that go right to the edge), you all would be precisely at the altitude limit because of how accurate our instruments are at sensing relative changes. Because of your instruments low bias error, however, the recorded a QNE pressure altitude in your track log, when adjusted for the correct QNH of the day by the scorekeeper, would have you violating the airspace by the altitude difference corresponding to your instruments bias error and you risk a penalty.

If instead, you set your instrument up for the task board QNH, your A1 would read a bit high at launch. Then during the flight when all the other pilots without bias errors go right to the limit, you would be below them looking at your A1 indicating that you were at the limit and thinking they were cheating. The good news about this case is that when you set the task board QNH and keep your A1 below the limit you will avoid a penalty. To complete the mind bending exercise, it will be "left to the student" to go through the opposite case to see the similar issues, only the other way around.

The good news is that our instrument manufacturers are pretty darn good at what they do and build, so we are talking about +/- 10-ish meters here, not a hundred. That said, for those comp pilots that want to be right on the edge of what instrument accuracy allows, many instruments can be calibrated by the factory. CIVL is also considering ways the scoring system software can determine and account for instrument bias errors and automatically apply the bias error to the track logs, but that is still a ways away.

Summary

All that was discussed above boils down to just one or maybe two things for you to do. 1) Adjust your A1 correctly at launch for the known MSL altitude and, if necessary because of your bias error, 2) Adjust the A1 reading considering the calibration error of your instrument or get the manufacturer to recalibrate the pressure sensor. Doing those two things should get your A1 altimeter to read as close as you can get it to keep you out of trouble with the scorekeeper. If you can keep your eye on A1, your fellow pilots and avoid the cloud suck if the airspace limit is near cloud base (as it was in Brasilia - dealing with that problem is another good topic!) you'll be a steely eyed killer of a competitor while avoiding getting a zero for the day.

A last word to those pilots who may want to say this is too complicated and we should change the rules to be more lenient about air space violations. If you want to fly around restricted airspaces, learn how to be a pilot! As much as I like flying with the bare minimum of rules (that is a big reason why I fly hang gliders), if we want to be allowed to fly in and around the restricted airspaces that "the real pilots" use, it is our obligation to know how to fly our craft in accordance with the rules. There also is a very easy answer on how to avoid an airspace violation penalty. Have a big buffer zone below the airspace– say 100 meters– and you'll be fine just setting your instrument to launch altitude and having at it!

P.S.

Another effect to consider in the accuracy of your A1 display is that the pressure of the day will change as the weather changes or as we fly into different areas on the task and hence the QNH setting required for A1 to read accurately changes. Since we typically fly in nice weather that isn't super windy (higher winds mean more pressure change with distance – that's why the wind blows hard!) or over weather fronts, pressure changes over our task days are only on the order of a millibar or two or three. With one millibar pressure change being equivalent to about 8 meters, our A1 might develop as much as a 25 meter error if it is windy or the weather is changing. This is only a "P.S." since your altitude is evaluated based on the single QNH posted on the task board, as it is not (yet?) reasonable to have pilots adjust for changing QNHs as they fly along during the task. What "the real pilots" do is fly by Flight Level when they are high and have transition altitudes below which they switch to real time QNH adjusted altitudes that they get by several means.