Analysis of Altimetry System Error

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Abstract

Aircrafts track their height in the sky or their altitude using an altimeter and GPS. The altimeter is responsible for measuring the pressure altitude based on air density in the area relative to a fixed level. The GPS measures geometric altitude. During a flight, the geometric altitude may change by hundreds or thousands of feet while the pressure altitude may remain constant. This discrepancy can be adjusted by incorporating the meteorological conditions. After the adjustment of pressure altitude, the heights may still differ, and this is known as altimetry system error (ASE). ASE was calculated and analyzed based on six sets of flight data provided by the Federal Aviation Administration (FAA).

Background

The FAA sets standards on how far apart two aircrafts may be during flight. This standard is based on an aircraft's flight level which is defined as an aircraft's altitude at 100 feet intervals. For example, FL 380 represents an aircraft with an altitude of 38,000 feet. Aircrafts may fly with a separation of 1000 feet until they reach FL 290. After this flight level, they must fly with a separation of 2000 feet due to increased error when using altimeters at higher altitudes. Incorporating meteorological data with the pressure altitude can minimize the altimetry system error which can allow aircrafts to have a more accurate idea of where they are when they fly. In a world where air travel is on the rise, air space is valuable. A more accurate altimeter can allow reduced separation between aircrafts and more aircrafts to fly safely in the future.

References

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Methods

Because we were given data from 6 sets of flights from the FAA, we were able to analyze the given pressure and geometric altitudes for each flight at any given time. Using those given altitudes and the equations to the right, we were able to create a model and estimate the height of the aircraft. The equations to the right allow us to find the acceleration due to gravity based on the geometric height and the relationship between pressure altitude and meteorological conditions. The information that we are looking at represents hours of data, so a robust model was needed to handle thousands of calculations.

The programming language R was used to handle all the given data and equations. R is a powerful language used to calculate and graph our results. Meteorological data was read and saved using R and its rNOMADS package. Corresponding elevation data was downloaded using the elevatr package. From this point, R went through iterations of calculating the compiled data from excel sheets and saved workspaces to create an image of the flight path.

Equations Modeled

$$g(\phi, h_g) = g_0(\phi)\left(\frac{r(\phi)}{r(\phi) + h_g}\right)^2$$

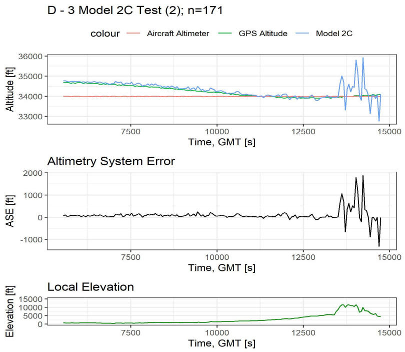
$$dp = -\rho g(\phi, h_g) dh_g$$

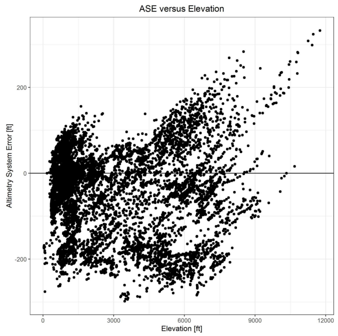
$$P = \rho RT$$

$$\ln \frac{P_2}{P_1} = -\int_{h_{g,1}}^{h_{g,2}} \frac{g(\phi, h_g)}{RT(h_g)} dh_g$$

Results

The flight data given by the FAA was made anonymous by labeling the flights with the letters A through F followed by a number to represent a specific flight level. After the latest model was created in R, known as model 2C, the calculated ASE dramatically went down. In the previous model, the ASE could average anywhere from 1000 to 6000 feet; however, the figure to the right shows that for flight D3, the ASE averaged a few hundred feet until the end of the flight. This reduction in ASE for the new model was a recurring pattern for our flight data. The dramatic spike in ASE for the figure may be due to the increase in elevation, which future models will have to take into consideration. The figure towards the bottom right represents ASE vs elevation and it aims to uncover a relationship between the two variables. While the points are spread out, there is some tendency for the ASE to increase as elevation increases. The direct cause of altimetry system error has yet to be uncovered, but future models will give us a better idea. Computing the data currently takes a lot of time, even with two people. Moreover, using only 6 sets of data has its limitations. We hope to uncover more relationships with ASE with more data and improved models in the future.





Future Direction

For future models, there are multiple things that we would like to take into consideration. First, elevation seems to affect ASE which can be seen in the figure to the left. We have already planned to create models that incorporate elevation and eliminate it to see the effect on ASE. Next, our current models assume that air is free of moisture which can affect the pressure on the aircraft. Future models plan on implementing the relative humidity of the air so that the moisture can be found based on the location. We have already begun to look at R packages and databases for humidity. Finally, the geometric height or the GPS altitude is currently taken as the standard that we base our accuracy on; however, there is most likely error in the GPS as well. We plan on finding the error in the GPS and adding error bars to give us an accurate representation of the aircraft path.

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