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TITLE: Relationship between Barometric Altitude and GPS-Based Height

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SUMMARY

The NWP (numerical weather prediction) data is available to make a correction to the barometric altitude. Corrected altitude might augment GPS-based altitude in terms of integrity and continuity.

1. Introduction

The author investigated the absolute error characteristics of the barometric altimeter affected by the local atmospheric conditions. Employing correction procedure based on the NWP (numerical weather prediction) data, barometric altitude can be converted into the accurate height information and thus available for augmentation of GPS-based altitude in terms of integrity and continuity.

2. Background

The barometric altimeter is widely used for measuring altitude of the aircraft, giving means of vertical navigation and separation among the airspace. The measurement accuracy of the barometric altimeter largely depends upon conditions of the real atmosphere; measurement error sometimes reaches 10 percent of the true height. This kind of measurement error is not a problem for vertical separation of aircraft because the relative accuracy can be maintained small enough for separation purpose.

However, sometimes we need height sensor which measures the absolute altitude accurately; obstacle clearance, weather/science observation, hybrid navigation with GPS, and so on. Essentially it is possible to employ GPS-based altimeter for vertical navigation and separation, but the appropriate conversion procedure between barometric altitude and GPS-based altitude must be provided, at least during transition phase.

On the other hand, it is known that GPS (and SBAS) is vulnerable to radio-interference when used for safety-of-life applications. Any vertical position sensors could augment integrity and continuity of GPS against this kind of vulnerability; the barometric altimeter is suitable for this purpose. Again, we need the accurate conversion procedure between barometric altitude and GPS-based altitude in order to achieve the augmentation through precision approaches.

The author has investigated the relationship between two height sensors: especially the absolute error characteristics of the barometric altimeter. Using the numerical weather prediction information, one can estimate the indication of the barometric altimeter only from GPS-based altitude instead of measuring the real air pressure; it is feasible to implement synthetic pressure altitude (SPA).

3. Correction to Barometric Altitude

The barometric altimeter is basically an equipment which converts air pressure into the height above the mean sea level based on the standard atmosphere defined by the ICAO. The measurement accuracy of the barometric altimeter largely depends upon conditions of the real atmosphere; the actual error sometimes reaches 3,000 feet at the height of 30,000 feet. The variation of surface pressure shifts the indication of altimeter at the low altitude, while vertical profile of air temperature affects at the high altitude. Local gravity variations and tidal effects also induce a little change of the indication of altimeter.

In order to utilize the barometric altitude as an augmentation to the GPS, measured altitude should be corrected based on the local atomospheric conditions. In other words, the appropriate conversion procedure between barometric altitude and GPS-

based altitude is necessary. The requirement to the accuracy of the conversion depends on the flight phase for which the augmentation applied. For a precision approach phase of flight, local weather observation at the airport should be used for correcting barometric altitude; QNH setting is an example of such correction.

For enlargement of the coverage of the correction to all phases of flight at any location, we need regional (or global, hopefully) weather information with uniform accuracy. The author developed such a correction method using the numerical weather prediction (NWP) information provided by Japan Meteorological Agency (JMA).

4. Experimental Results

The author conducted the flight experiments with barometric altimeter and GPS receiver onboard. During the experiment for three days in winter season, the variation of surface pressure was up to 20 hPa. The experimental aircraft flew 1,500 km southwestward from Tokyo and returned on the same way. In general, at the southwestern part of Japan it is wet and warm, different from the standard atmosphere.

The results showed that the barometric altimeter involved measurement error of 45 meters RMS on the ground without any corrections while the proposed correction procedure using NWP data reduced the error to 12 meters RMS. The maximum error was 118 meters for the raw altimeter, and 27 meters with the correction. The measurement error tends to grow a little above the ocean because of few observation sites. Figure 1 illustrates the height measurement error on return trip.

5. Conclusion

The NWP (numerical weather prediction) data is available to make a correction to the barometric altitude. Corrected altitude might augment GPS-based altitude in terms of integrity and continuity.

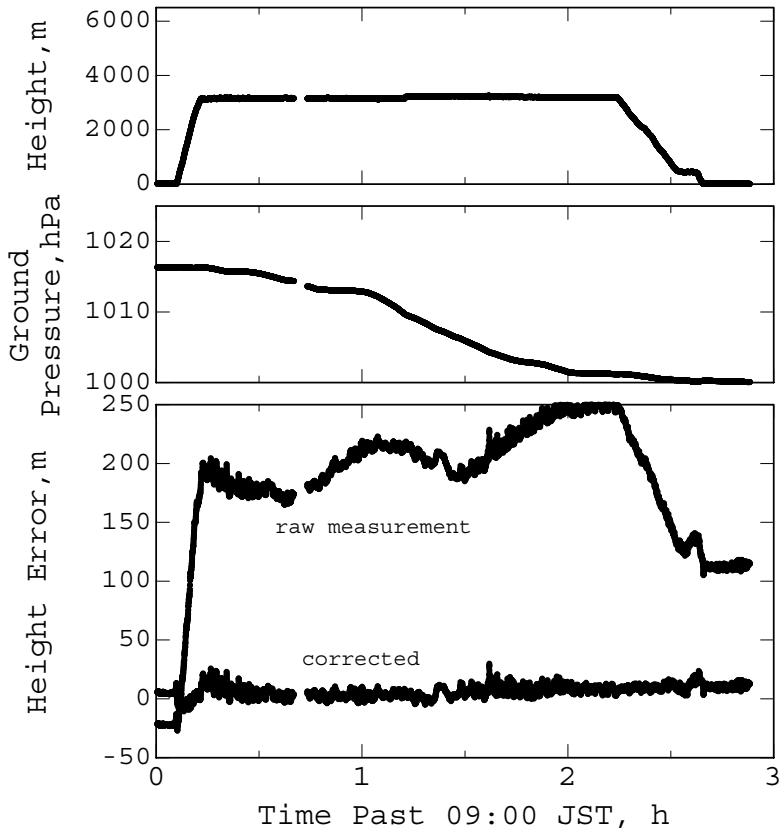

Figure 1 Comparison between raw measurement and corrected altitude.