A Comparison of Altimeters Used in Aerial Photogrammetry

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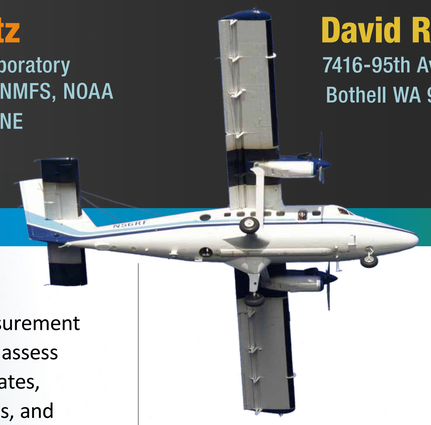

Introduction

- Body length is a fundamental measurement in wildlife studies and is needed to assess population size structure, growth rates, maturity status, habitat preferences, and allometric relationships.
- Photogrammetric methods, using an aerial platform, provide a practical method to obtain length measurements of marine mammals.
- A critical component to documenting lengths through photogrammetry is to accurately establish the aircraft's altitude, or the distance between the camera and target.
- Although most aerial photogrammetric studies rely on radar altimeters to provide reliable and accurate altitude measurements, there are currently several instruments on the market designed to measure altitude such as GPS altimeters (barometric and satellite), and laser altimeters.

Objective

In this study, we compare measurements from radar, laser, and GPS (barometric and satellite) altimeters relative to the 'true' altitude calculated from precisely measured calibration targets.

Methods

- We conducted altimeter calibrations from a NOAA DeHavilland Twin Otter in September 2009, 2010, and 2011 in Barrow, Alaska.
- A calibration target consisted of 3.5 × 24.0 cm painted boards set in a "t" configuration (Fig. 1A-B). When calibration boards were not available, the runway identification numbers painted on this airstrip were used (Fig. 1C-D).
- A Canon EOS-1DS Mark III digital camera was vertically mounted over an open hole in the floor of the aircraft (Fig. 2A-B). A 50 mm (2009) and an 85 mm (2010, 2011) fixed focal length lens was manually focused to infinity.
- Altitudes were collected from a handheld Garmin 76CSx GPS (barometric and satellite), radar, and laser altimeter.
- We flew over the land-based calibration target at 30.5 m (100 ft) increments from 152.4 to 457.2 m (500 to 1500 ft) at a speed of 185 km/h (100 kt).

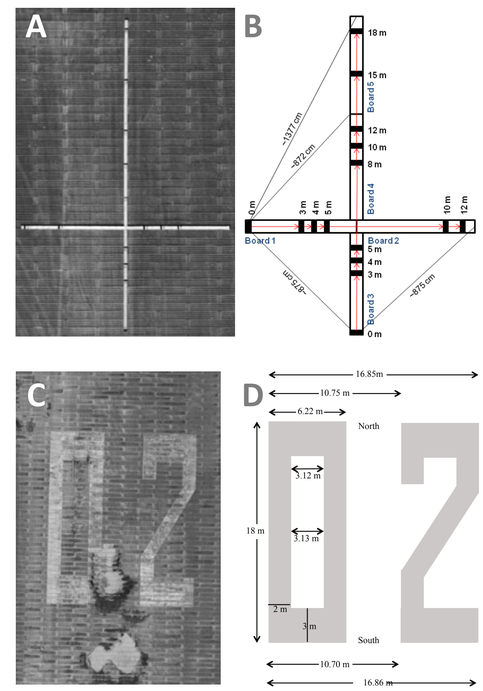

Figure 1: Aerial images and schematics of two land-based calibration targets used to determine exact altitudes during photogrammetric surveys conducted near Barrow, Alaska, 2009-2011.

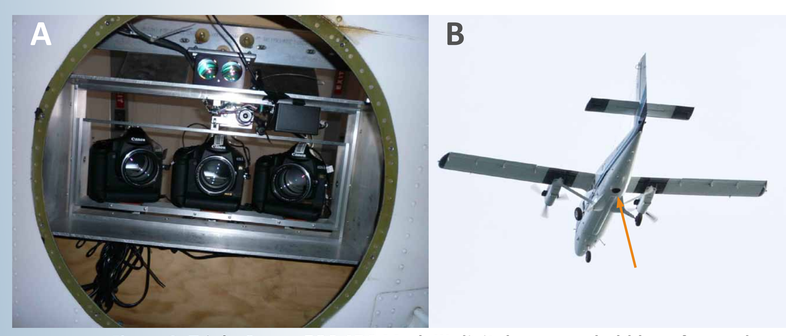

Figure 2: Triple Canon EOS-1DS Mark III digital cameras held by a forward motion compensation mount in the belly of the aircraft. Only the center (vertical) camera was used for photogrammetry.

Results

- Recordings from all four altimeters were highly correlated with the calculated "true" altitude values (r2 > 0.99).
- Using the regression equations for each altimeter relative to the 'true' altitude, we standardized the altimeter readings to correct for any differences due to sensor height.
- In 2009 and 2011, all altimeters recorded measurements closer to the 'true' values than in 2010 (Table 1).
- During these two years, the measurements from the radar altimeter were significantly better than both the satellite GPS (T2009 = -2.75, p = 0.01, df = 25; T2011 = -2.95, p = 0.01, df = 15) and laser altimeter measurements (T2011 = -2.90, p = 0.01, df = 15).
- Measurements obtained by the GPS's barometric altimeter were not significantly different than the measurements from the radar altimeter except in 2010 (T2010 = -3.98, p < 0.01).
- Both the GPS's barometric and radar altimeters exhibited significant differences in accuracy between years; the radar altimeter was more accurate in 2011 than 2010 (F1,33 = 5.71, p = 0.02).
- The measurements from the barometric altimeter were significantly more accurate in 2009 (F1,43 = 7.15, p = 0.01) and 2011 (F1,33 = 6.08, p = 0.02) than measurements recorded in 2010.
- Combined across years, there was no consistent pattern of under- or over-estimation of altitude measurements for any of the four altimeters (Fig. 3)

Table 1: Average absolute difference (m) and standard deviations between 'true' measurements and regression-corrected measurements recorded by four different altimeters

Year	Radar	Barometric	Satellite	Laser
2009	1.62 ± 2.29	1.77 ±2.71	2.56 ± 3.77	NA
2010	2.47 ± 3.46	3.85 ± 5.09	4.12 ± 5.59	3.63 ± 4.67
2011	1.02 ± 1.21	1.69 ± 2.34	2.28 ± 2.93	2.23 ± 2.79
Overall	1.72 ± 2.48	2.39 ± 3.50	2.79 ± 4.18	2.99 ± 3.87

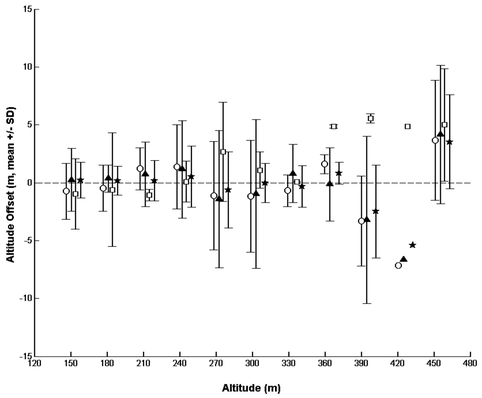

Figure 3: Difference between corrected altitude measurements ('truth') and altitude readings from four altimeters: laser (squares), barometric (circles), radar (stars), and satellite (triangles). Black lines represent standard deviations when more than one photograph was available in a 100 meter bin.

Conclusions

- Results from this analysis indicate that the GPS's barometric altimeter provides comparable measurements to those obtained from a radar altimeter and may provide a reliable and inexpensive alternative.
- The radar altimeter produced the most accurate results followed by the GPS's barometric, GPS's satellite, and the laser altimeter.
- While barometric altimeters are fairly accurate, care must be taken to calibrate the unit before each flight, using either known barometric pressure or elevation.
- Because barometric altimeter readings vary with atmospheric pressure, this method may be unreliable for precision photography during rapidly changing weather conditions.
- The lower accuracy of all the altimeters in 2010 is likely due to inexperienced pilots that were unable to keep the speed, pitch, and heading of the aircraft consistent between passes.
- Although the radar altimeter tested here was more accurate and precise than the GPS barometric altimeter, there is a large difference in cost (>$24,000).
- The loss in accuracy and precision between the radar and GPS's barometric altimeter might be a factor only when animal targets are small or maximum precision is needed in estimating body lengths.

Acknowledgements: We thank the Bureau of Ocean Energy Management for funding this research, especially Chuck Monnett and Jeff Denton. NOAA AOC provided able pilots and mechanics. Craig George assisted with the calibration target. Photographs were examined by Julie Mocklin, Linda Vate Brattström, and Kelly Trask. This study was conducted under NMFS research permits 782-1719 and 14245.

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