



# ACCURACY ASSESSMENT ON DRONE MEASURED HEIGHTS AT DIFFERENT HEIGHT LEVELS

David L. Kulhavy, I-Kuai Hung, Daniel R. Unger and Yanli Zhang  
Arthur Temple College of Forestry and Agriculture

## Summary

A DJI Phantom drone was tested for height measurement at four different levels, 2, 5, 10, and 15 m above ground along a height pole. The results revealed it measured height more accurately when the drone was landed and took off before each measurement, while having the GPS on or off did not make any difference.



## Introduction

The advancement in unmanned aerial system (UAS) technology has made it possible to attain an aerial unit, commonly known as a drone, at an affordable price with increasing precision and accuracy in positioning and photographing. While aerial photography is the most common use of a drone, many of the models available in the market are also capable of measuring height, the height of the drone above ground, or the altitude above the mean sea level. On board a drone, a barometer is used to control the flight height by detecting the atmospheric pressure change; while a GPS receiver is mainly used to determine the horizontal position of the drone. While both barometer and GPS are capable of measuring height, they are based on different algorithms. Our study goal was to assess the accuracy of height measurement by a drone, with different landing procedures and GPS settings.

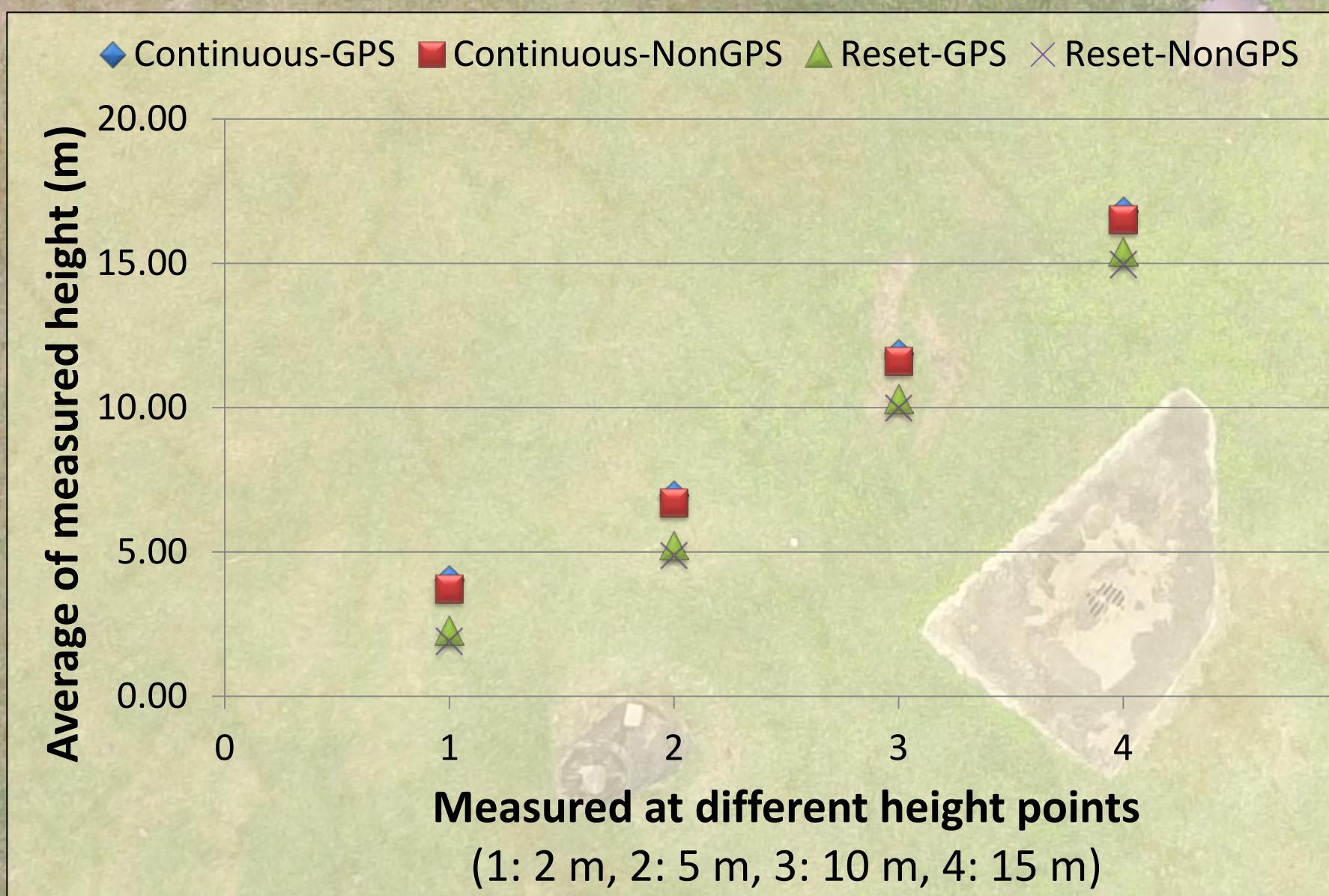
## Methods

In our study, we tested a DJI Phantom 3 drone on its accuracy in measuring height. We flew the drone along a height pole at four different height level marks, 2 m, 5 m, 10 m, and 15 m above the ground. When the drone was hovering at a height mark, the height reading of the drone displayed on a remote control screen was recorded and compared to its real height on the height pole. This process was repeated with different settings of whether having the GPS on or off; and whether landing the drone before each measurement or having the drone continue to fly to different height level marks. It's a combination of four settings, with each setting repeated for 30 times. Data collected were analyzed by calculating height measure errors for average, standard deviation, and root mean square error (RMSE) of each setting. For each of the four height levels measured, a two-way analysis of variance (ANOVA) was conducted on the absolute errors of height measurement to determinate if there was any interaction between the two factors, GPS and landing settings, on accuracy, if any setting achieved higher accuracy than others.

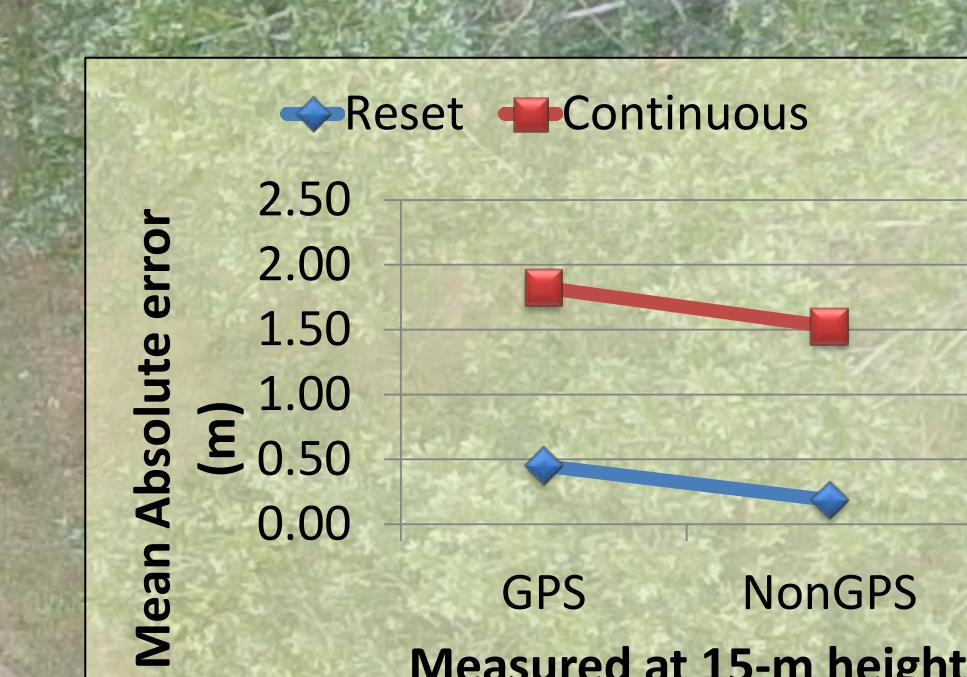
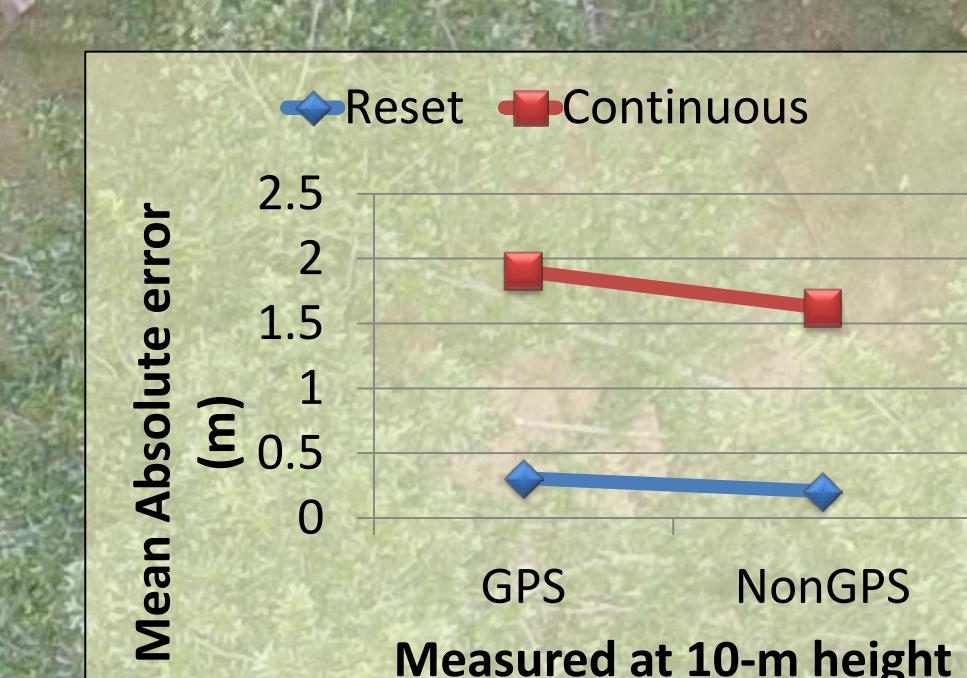
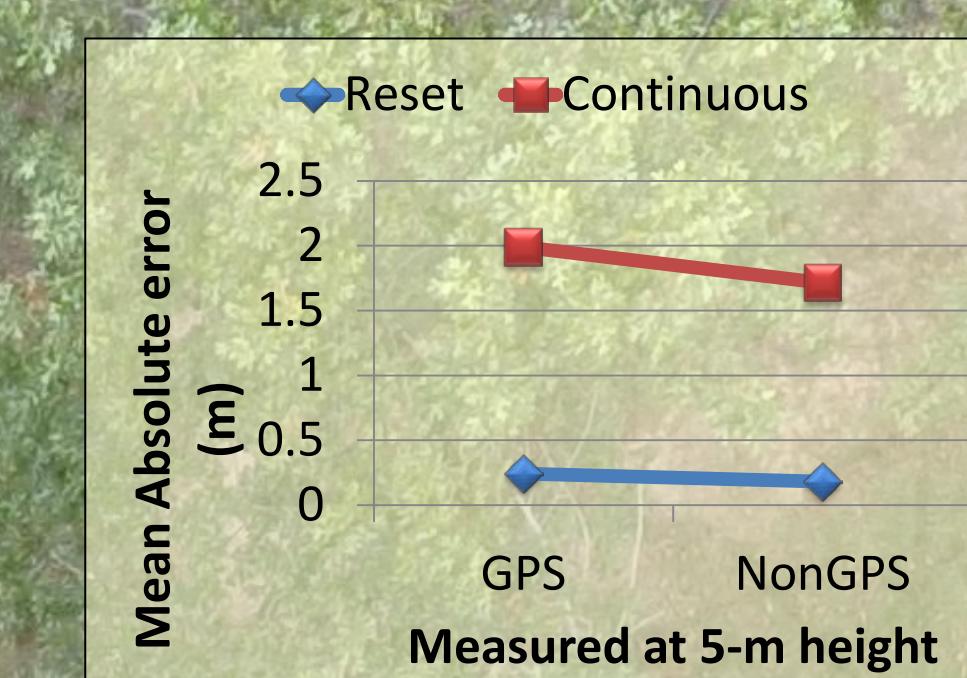
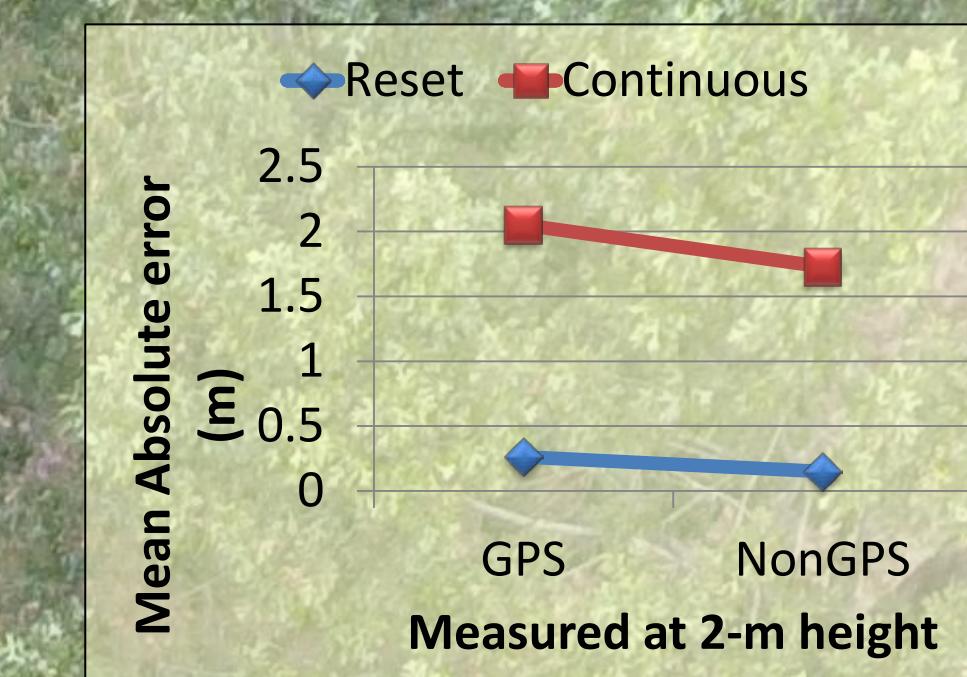
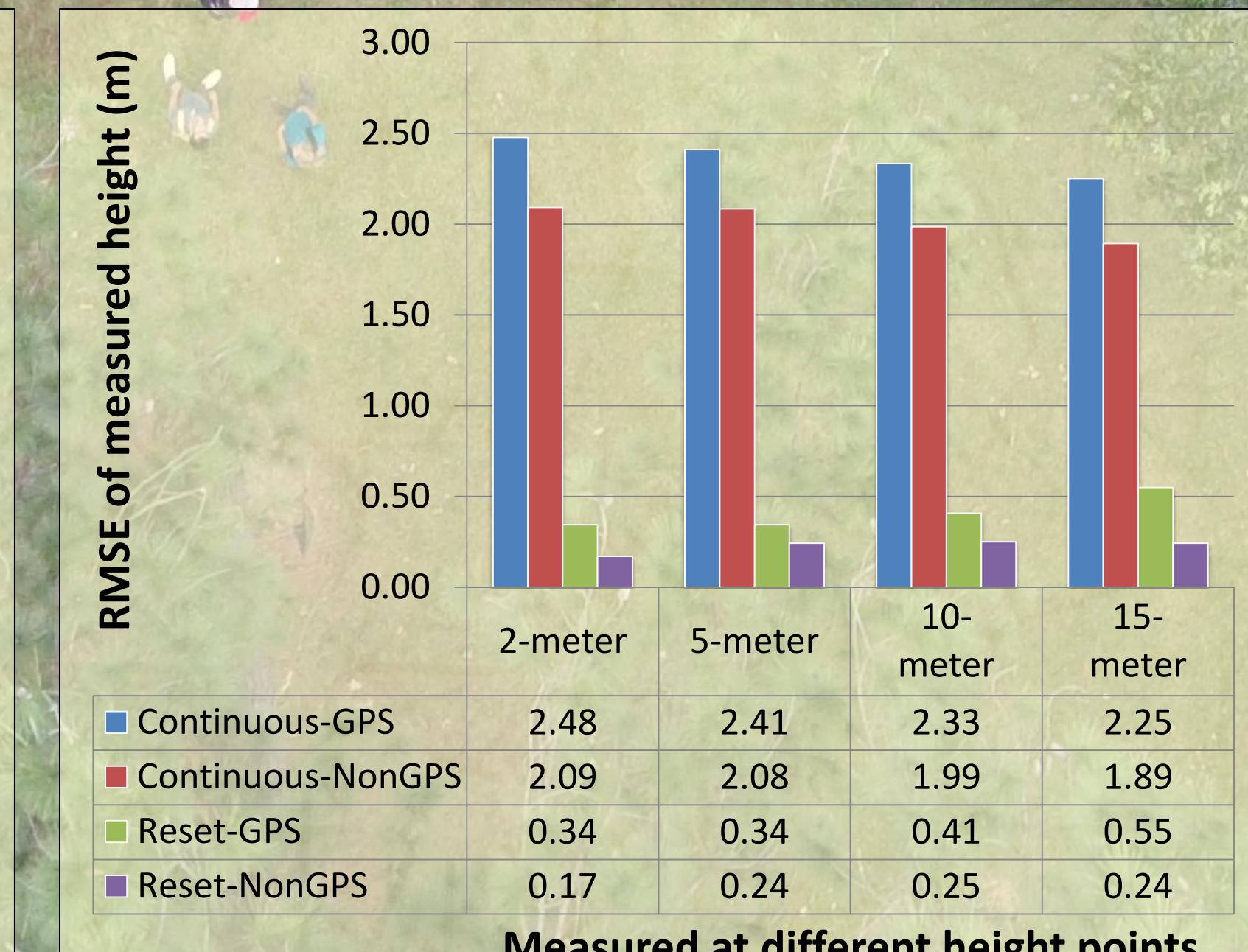
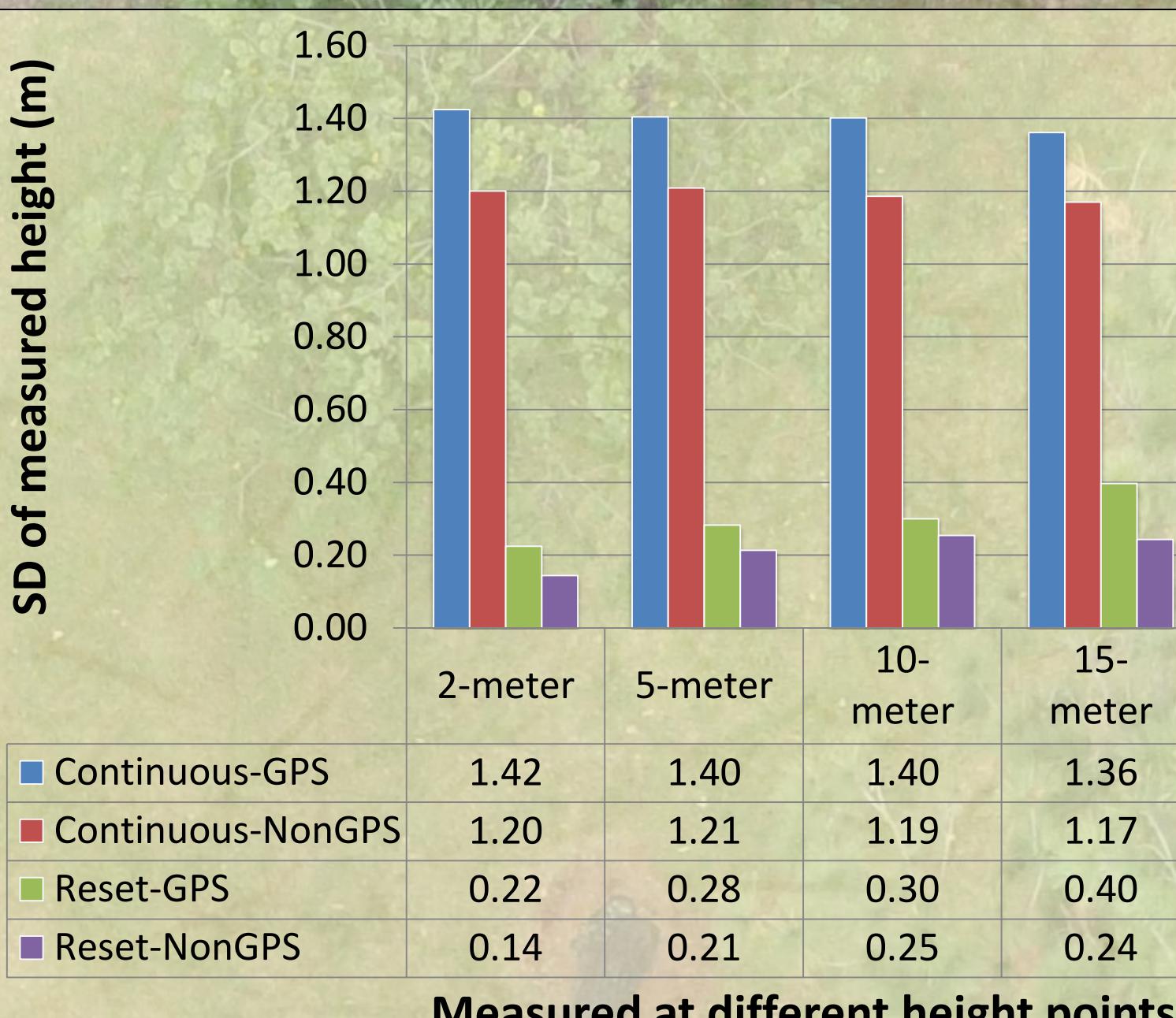


## Results and Discussion

- A total of 480 height measurements were recorded, 4 combinations (landing and GPS) at 4 height levels (2, 5, 10, and 15 m) with 30 repetitions each.
- Averages of measured heights showed that having landing reset resulted in values closer to the actual height at all height levels, while non-reset tended to overestimating the height. Having GPS on also contributed to overestimating the height, but to a much less extent than landing non-reset.
- Standard deviations of measured heights revealed low measurement precision when landing was not reset. This higher variation was also found when GPS was on, although not as obvious as landing non-reset.
- RMSE confirmed that having landing reset without GPS on achieved the highest accuracy (RMSE = 0.17 m), while having no landing reset with GPS on was the least accurate (RMSE = 2.48 m).
- RMSE also revealed that accuracy decreased at higher measured levels when landing was reset, whereas accuracy increased when landing was not reset.
- At each height level, there was no interaction between the two factors , landing reset and GPS (p-values: 0.5209 – 0.9161). Having landing reset always resulted in higher accuracy regardless the GPS setting.
- No significance on the means of absolute errors was found between having GPS on and off (p-values: 0.2020 – 0.2501) at all height levels, except the 15-m measured point (p-value = 0.0887, having GPS on resulting in lower accuracy).
- The significant contributing factor was the landing setting. Having landing reset achieved significant higher accuracy at all height levels (mean absolute errors: 0.15 – 0.21 m, p-values: < 0.0001).
- The drone relies mainly on the barometer for measuring height that is referenced to the ground level. Although GPS is able to measure elevation, its low precision could often introduce error to the height measurement.



Average measured height (m)	2-meter	5-meter	10-meter	15-meter
Continuous-GPS	4.05	6.98	11.88	16.81
Continuous-NonGPS	3.73	6.71	11.61	16.50
Reset-GPS	2.26	5.20	10.28	15.39
Reset-NonGPS	1.91	4.88	9.99	14.96



Mean absolute error of measurement (m)	2-meter	5-meter	10-meter	15-meter
Continuous-GPS	2.05	1.99	1.90	1.82
Continuous-NonGPS	1.73	1.71	1.62	1.52
Reset-GPS	0.26	0.24	0.31	0.45
Reset-NonGPS	0.15	0.18	0.21	0.19

Source of Variation	2-meter		5-meter		10-meter		15-meter	
	F	P-value	F	P-value	F	P-value	F	P-value
Landing	97.22	0.00	93.19	0.00	81.25	0.00	68.13	0.00
GPS	1.65	0.20	0.99	0.32	1.34	0.25	2.95	0.09
Interaction	0.38	0.54	0.41	0.52	0.30	0.59	0.01	0.92

F-critical = 3.9229

## Conclusion

Remote sensing with its ability to collect data systematically, and in inaccessible areas, has the potential to aid field-based height estimation. The integration of drone technology was effective at estimating height and proved to be as accurate as traditional height estimates using a clinometer, laser range finder and LiDAR data. Repeated height measurements at four different locations along a telescopic height pole indicate the utility of using a drone to estimate height in the field. However, the study showed that to achieve the highest level of accuracy possible that the drone should land and be turned off before each flight to reset the elevation algorithm before each flight. A drone could be used to supplement or replace time consuming field-based height estimation and has the potential to revolutionize remotely sensed height measurements.