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A Quantitative Comparison of Traditional and Image-Derived Bathymetry From Landsats 5, 7, and 8

David Hulslander
Exelis Visual Information Solutions, Boulder, Colorado
david.hulslander@exelisvis.com

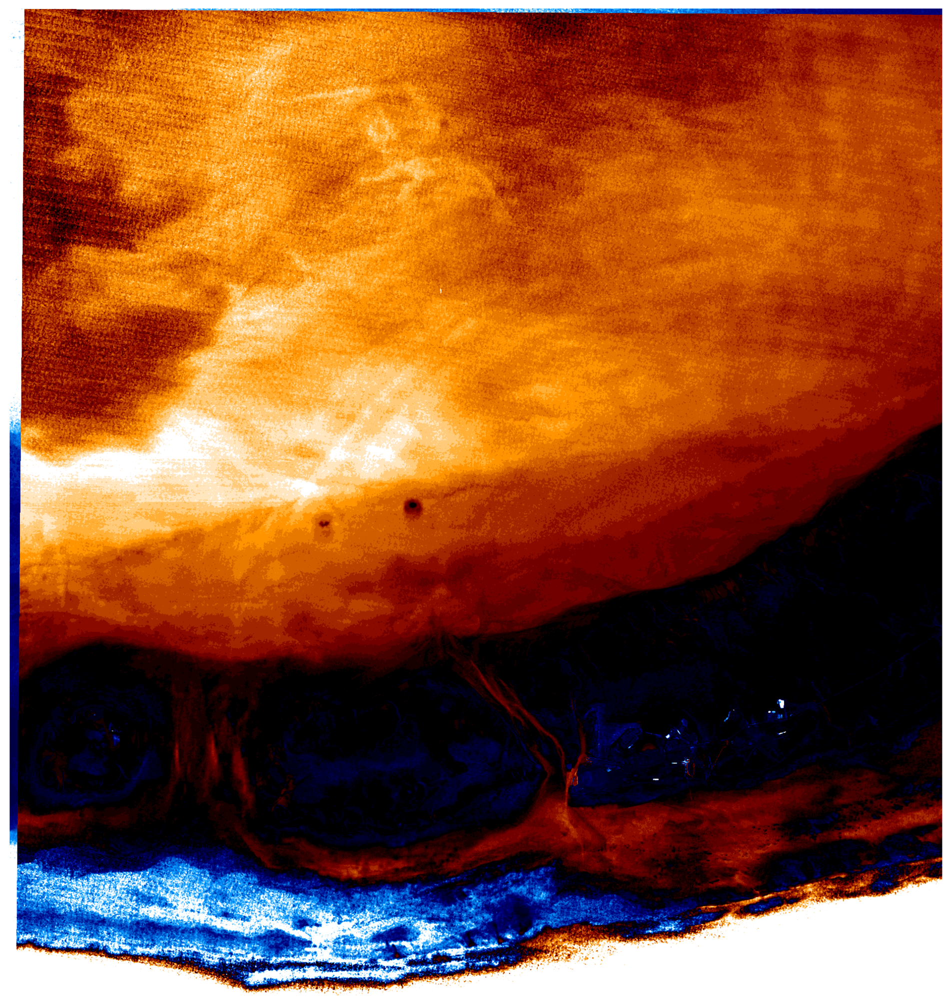

Figure 1: Study area bathymetry errors for Landsat 5. Black is zero, red is shallow by 1 to 15 m, blue is deep by 1 to 15 m Errors of more than 15 m are in white.

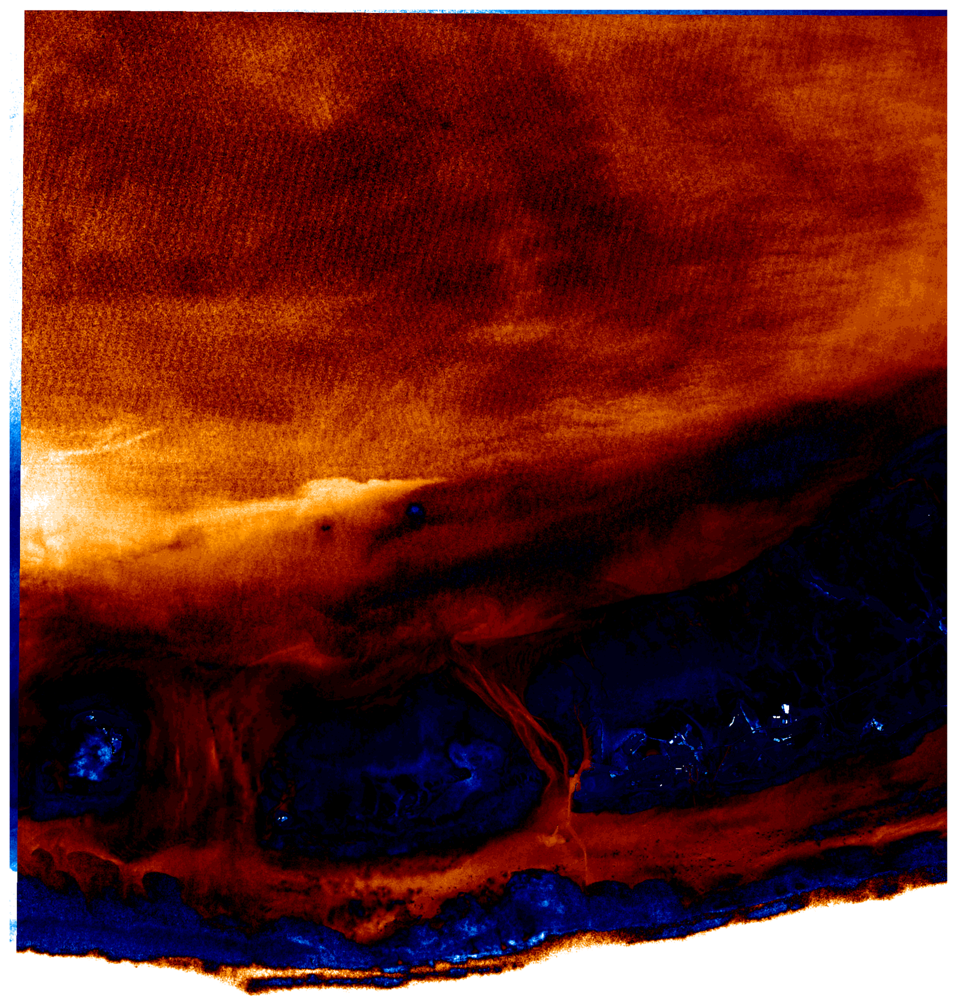

Figure 2: Study area bathymetry errors for Landsat 7. Black is zero, red is shallow by 1 to 15 m, blue is deep by 1 to 15 m Errors of more than 15 m are in white.

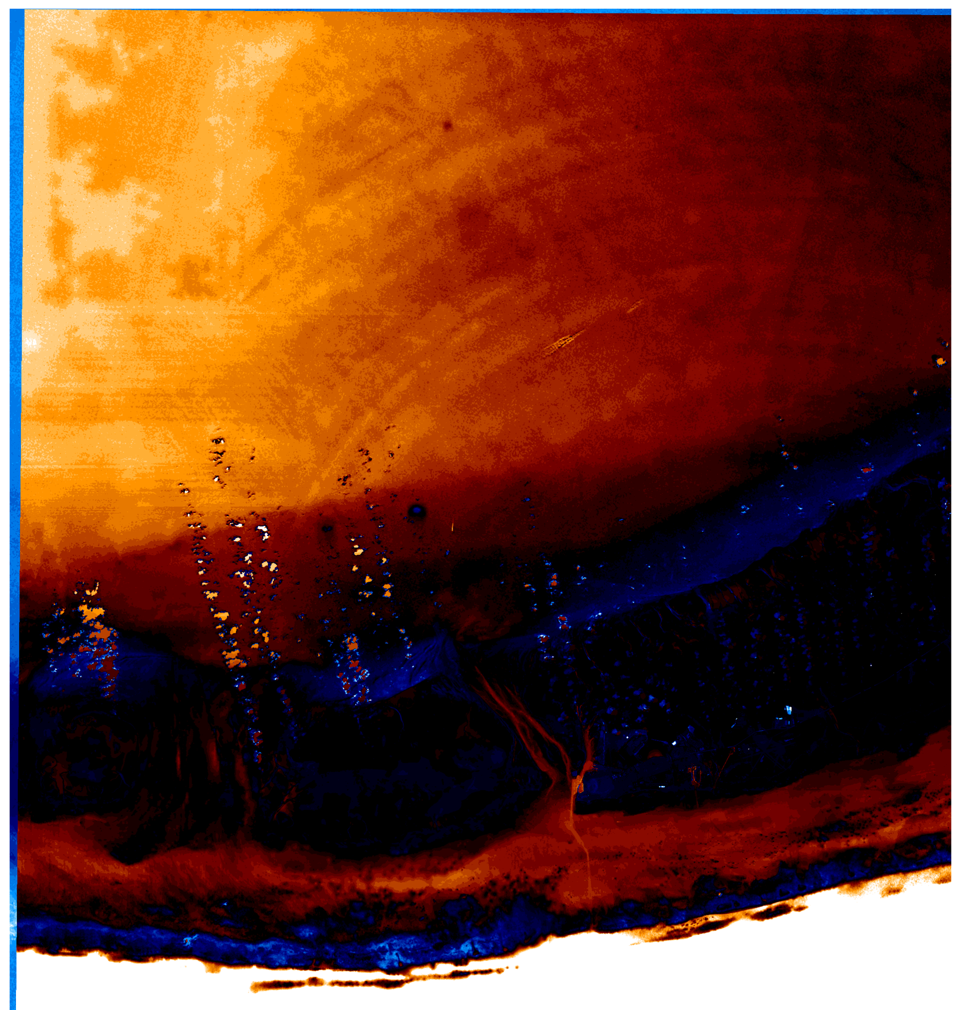

Figure 3: Study area bathymetry errors for Landsat 8. Black is zero, red is shallow by 1 to 15 m, blue is deep by 1 to 15 m Errors of more than 15 m are in white.

Introduction

Though the ocean covers 70% of the earth and is a prime driver of our climate, roughly 95% of it is unexplored. As a basic geophysical parameter, accurate and sufficiently detailed bathymetry is a key piece in understanding the oceans and coasts. Moreover, coastal bathymetry in particular can change rapidly in response to storms, sea level rise, changes in river conditions, and engineering activity. Because of the expense and time involved with traditional, though very accurate, bathymetric methods, remote sensing imagery-derived measurement is often used as a technique for in-fill or rapid response to bathymetry-changing events. While imagery-based bathymetry has been in use for many decades, the techniques and imaging platforms have both evolved and improved over the years. Landsat 8, with its added coastal band, 12-bit capability, 2-week revisit, and global coverage, is an important step forward in updating coastal morphology maps and extending them in to less well-known coastal waters. Here, we present results quantitatively comparing Landsat 5, Landsat 7, and Landsat 8 to sonar-derived bathymetry.

Methods

1. The waters around the Florida Keys were chosen for this study due to their variety of depths, water quality and clarity, and availability of Landsat and bathymetric sonar data.
2. Level 1G data for the study are were downloaded from the USGS Landsat data depot.
3. Landsat data were calibrated to at-sensor radiance per USGS documented gain/offset methods.
4. Atmospheric correction was applied to each Landsat scene using MODTRAN 5–based ENVI FLAASH tools.
5. Relative water depth was calculated for each scene using a bottom albedo-independent Log Ratio Transform bathymetry algorithm originally developed by Stumpf and Holderied (2003) and implemented in the ENVI SPEAR tools.
6. The relative water depth score of each non-land, non-cloud pixel in each scene was plotted against its corresponding known depth from NOAA sonar bathymetry data.
7. A calibration curve was fitted to this data and then applied to the relative water depth images to obtain calibrated water depths for each scene.
8. The calibrated depths were then differenced against the sonar depths and separated in to depth ranges (in meters: 0 to 5, 5 to 10, 10 to 15, 15 to 20, 20 to 30 and 30 to 40) for each scene, producing approximately 8.6 million comparison points.
9. Bathymetric accuracy was then compared against the sonar bathymetry as well as between the sensors, both statistically and geospatially.

Results

•Bathymetric accuracies for Landsats 5, 7 and 8 were similar in the 0 to 5 m depth range, with standard deviations of error as compared to sonar between 1 and 2 m.
•Landsat 8 consistently produces bathymetric results at depths greater than 10 m more accurate than Landsats 5 and 7. Standard deviations for bathymetric results in the depth range of 30 to 40 m for Landsats 5, 7, and 8 were 6.5 m, 3.4 m, and 2.9 m respectively.
•Landsat 8 bathymetric results show error ranges across all depths to 40 m consistently and markedly narrower than those seen with Landsat 5 or 7 data.
•Cloud cover and turbidity are the biggest sources of error outside of which sensor is used as the imagery data source.

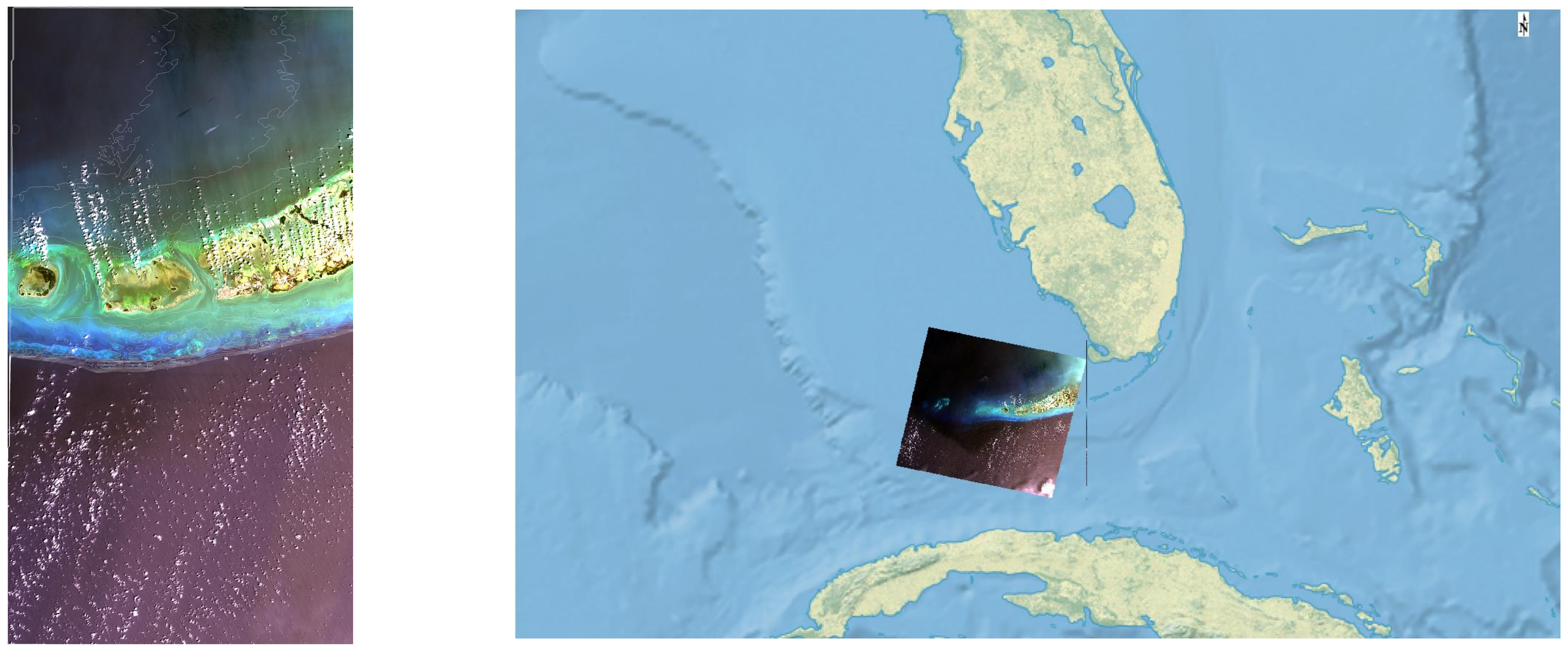

Figure 4: Study area. On right, Landsat 8 scene overlain in map context of greater Florida region. Actual extent of bathymetric comparison area at left.

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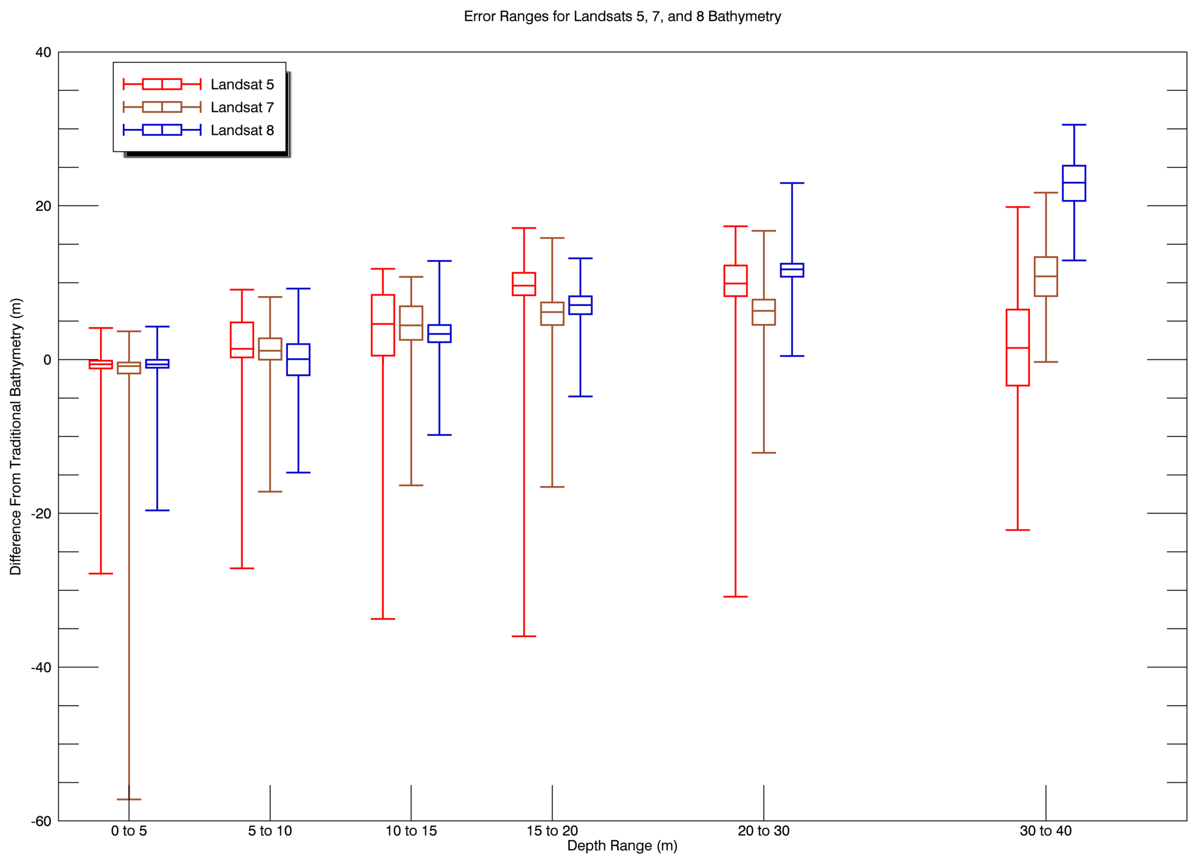

Figure 5: Low, high, quartiles, and medians of calibrated imagery derived depth error when compared to NOAA sonar data.

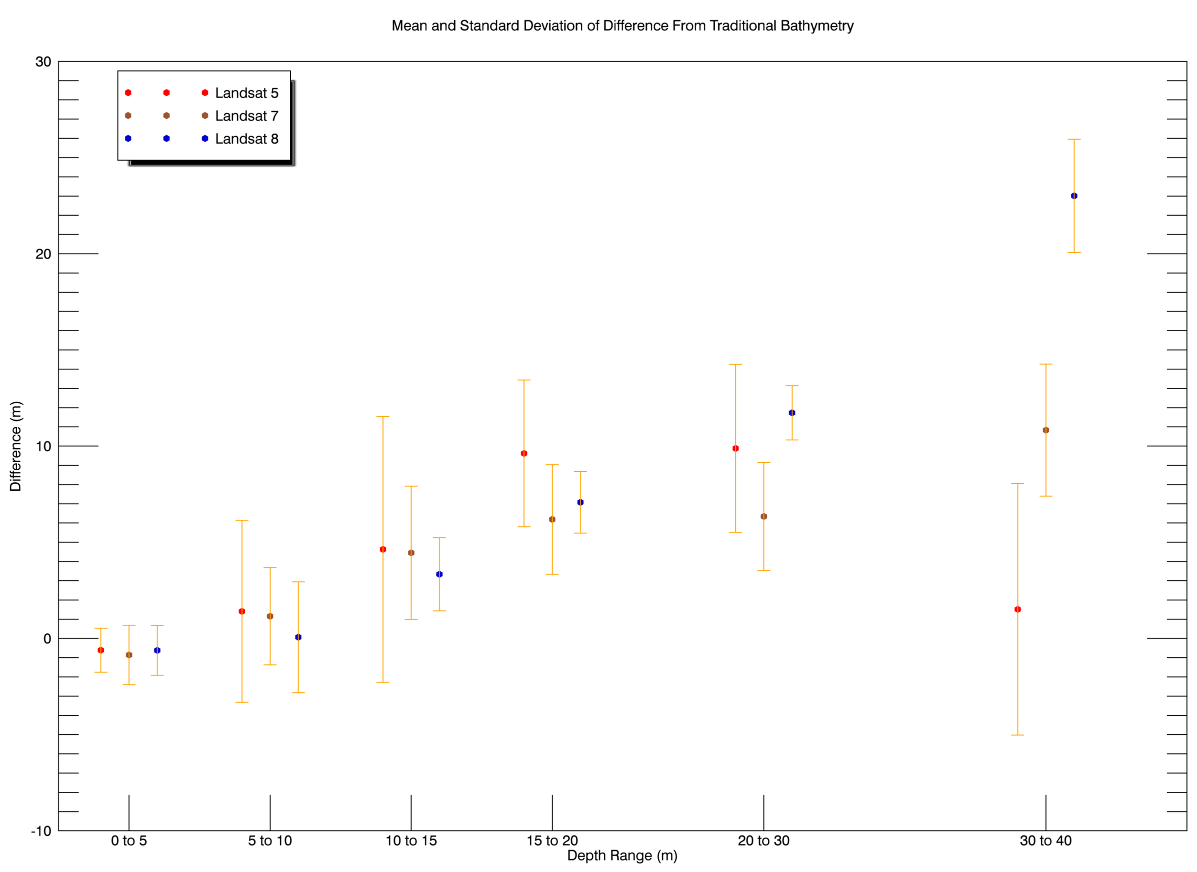

Figure 6: Mean and standard deviation of calibrated imagery derived depth error when compared to NOAA sonar data.

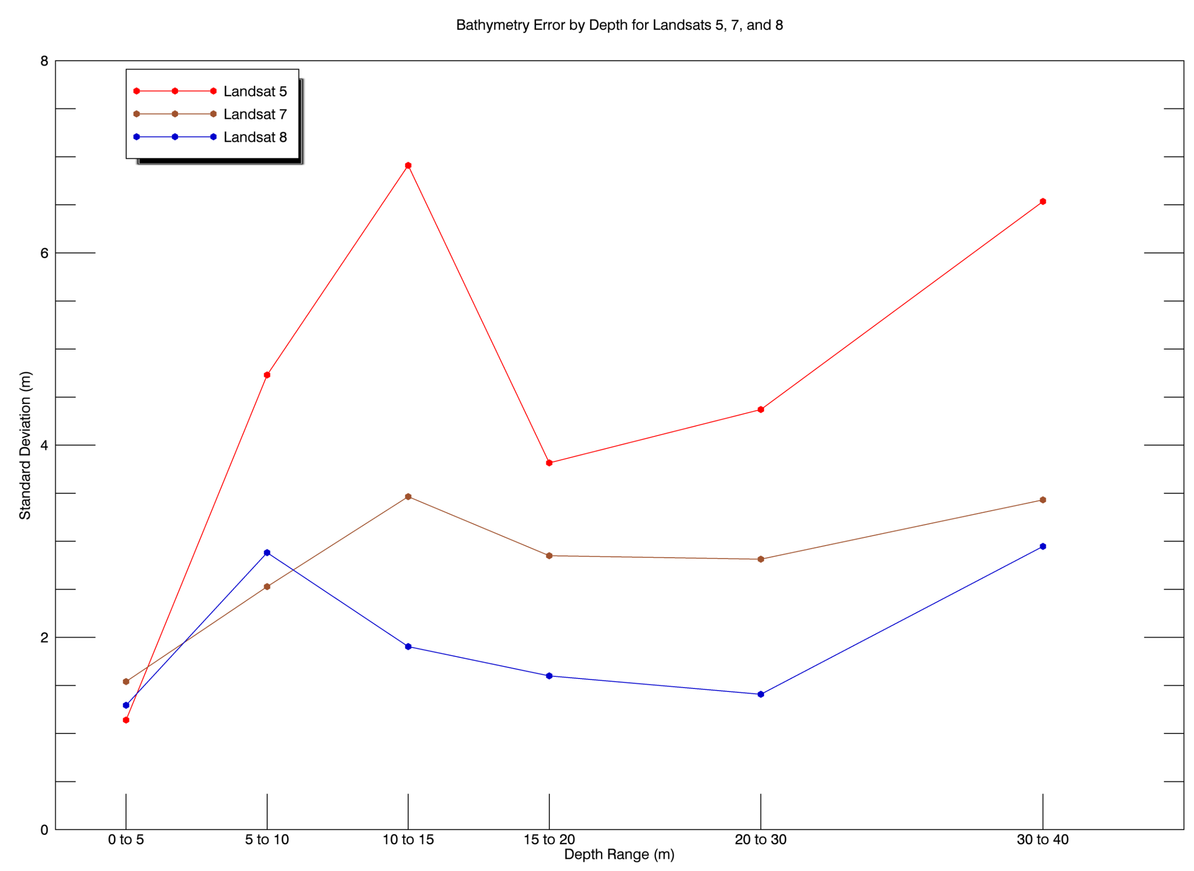

Figure 7: Standard deviation of calibrated imagery derived depth error when compared to NOAA sonar data.