An Assessment of DEM Extraction Methods from WorldView-1 Satellite Imagery

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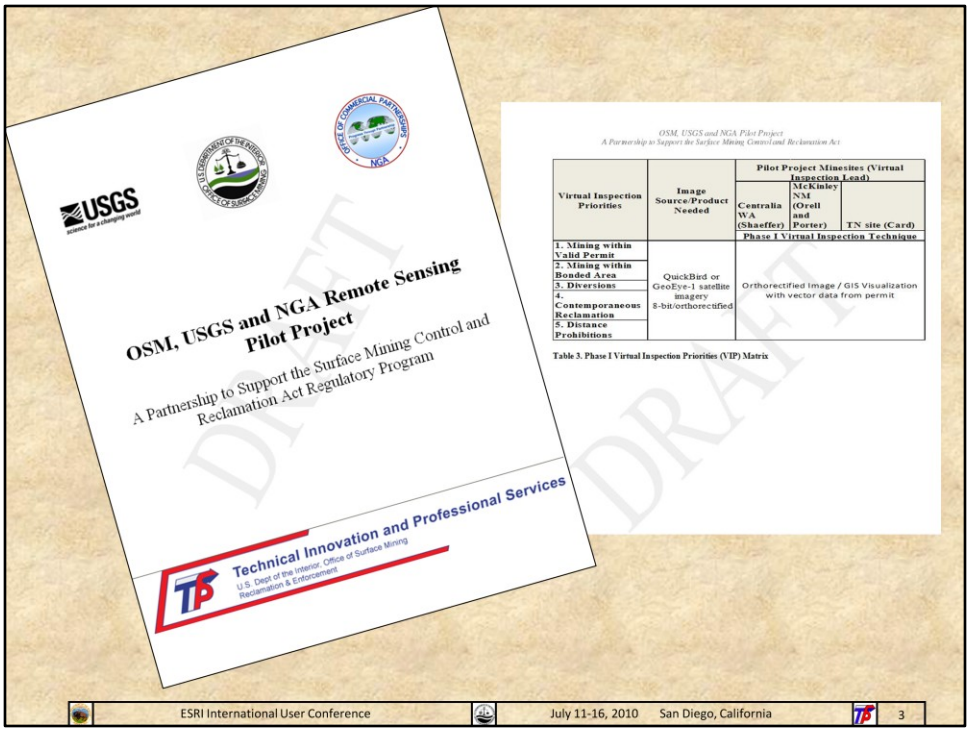
OSM, USGS and NGA Pilot Project Goals

- Work with NGA and USGS on satellite image acquisition for:
  - Centralia Mine, Washington
  - Valley Creek Mine, Tennessee
  - McKinley Mine, New Mexico
- Support the Surface Mining Control and Reclamation Act of 1977 (SMCRA)
  - Title IV – Abandoned Mine Land (AML)
  - Title V – Regulation of current mining

All three mines in the Pilot Project we are active mines, they fall under Title V of SMCRA



In the Pilot Project, over 50 Virtual Inspection Prioritiess (VIPs) have identified, but we are only focusing on 10. These have been broken down into two phases. The first phase, which is what we are working with now, covers:

1. Mining within a valid permit
2. Mining within bonded areas
3. Diversions
4. Contemporaneous reclamation
5. Distance Prohibitions

Both of the pages that you are looking at were taken from the Project Plan.

Our Part

We receive quarterly collects of multispectral and panchromatic imagery for the Pilot Project mines

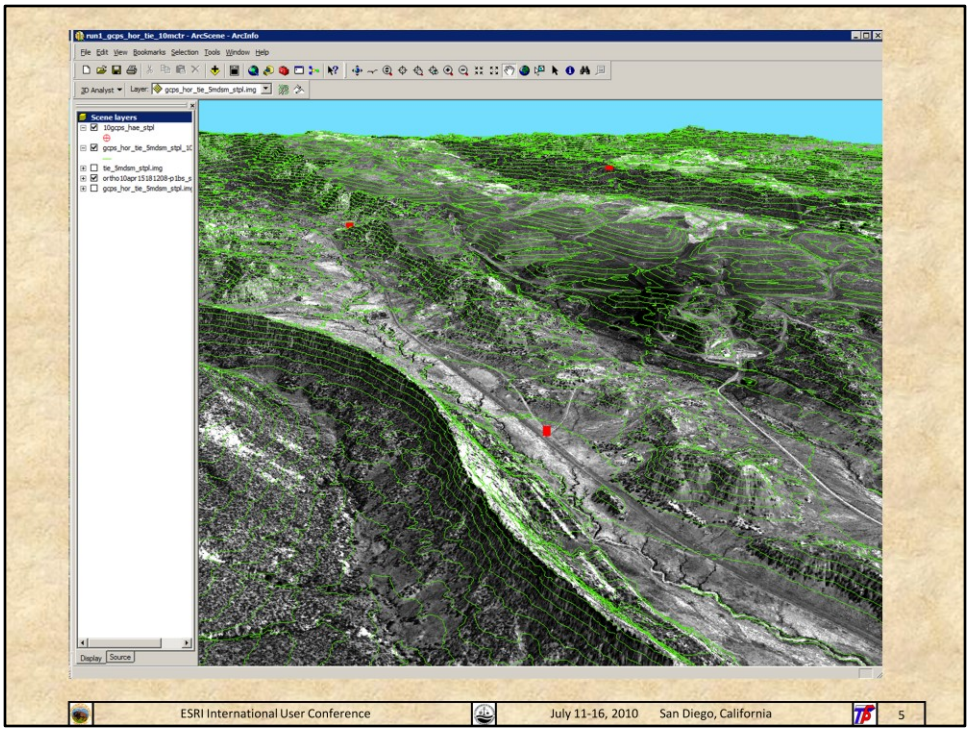
We provide orthorectified imagery and extracted DEMs for field offices and inspectors for:

- Visualization
- Analysis
- Terrain

Services provided need to be consistent, accurate, and repeatable

The work that is involved with imagery processing before delivering to the inspectors includes:

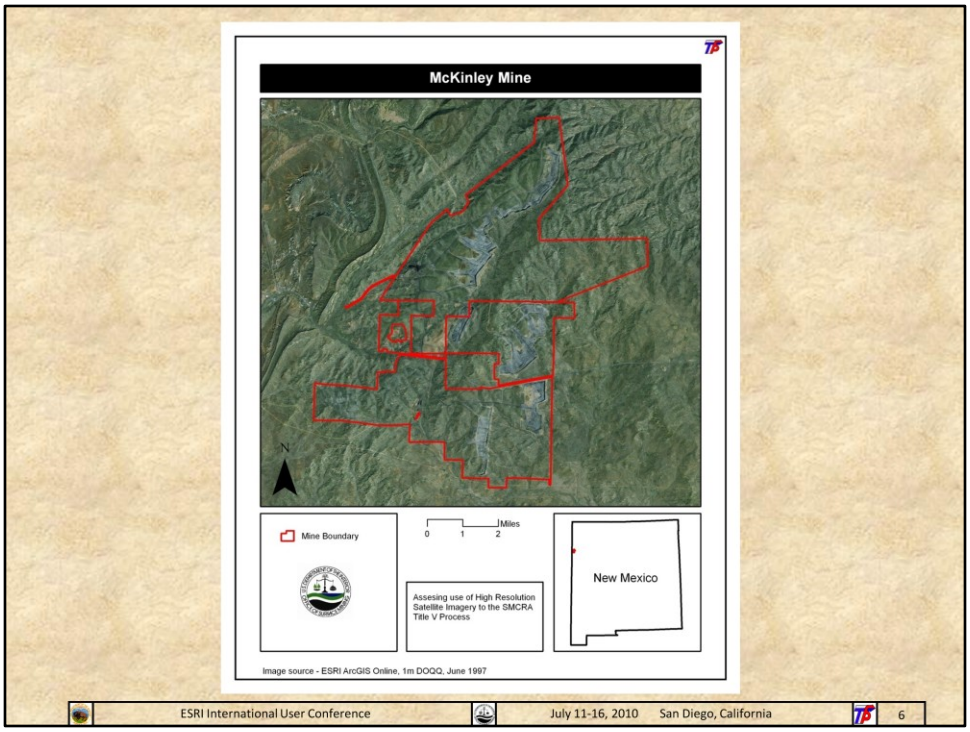
Orthorectifying
DEM extraction
PanSharpening
Contour generation from DEM
Color Balancing



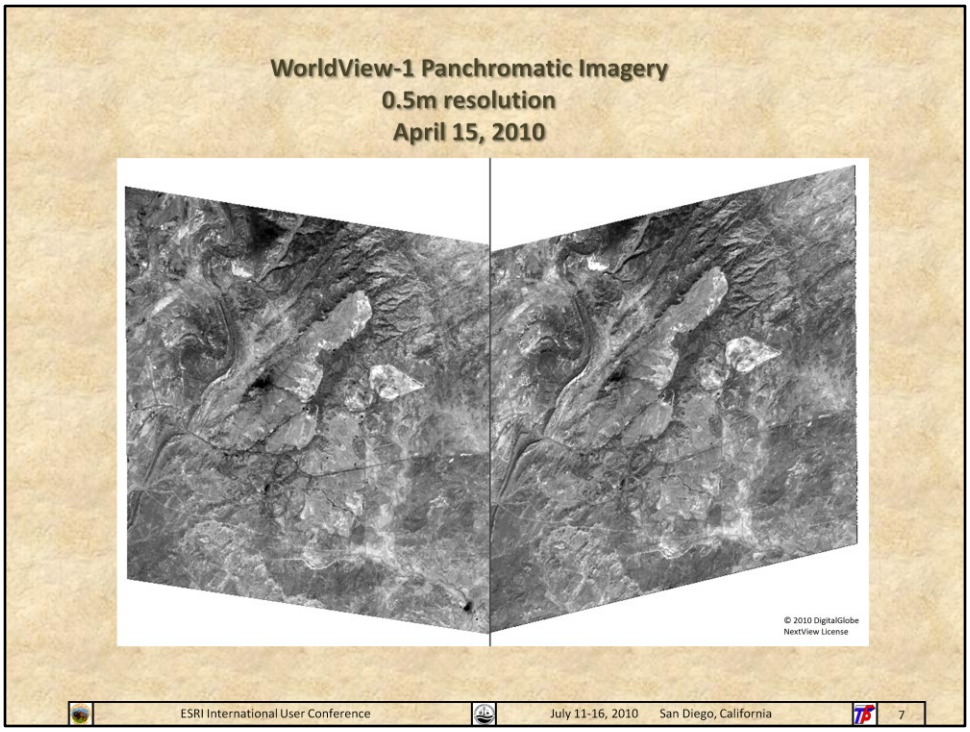
This illustrates processed imagery in ArcScene. You are looking at the orthorectified image draped over a hillshade making it 3D.

Green lines – 10 m contours

Red dots – Gcround Control Points



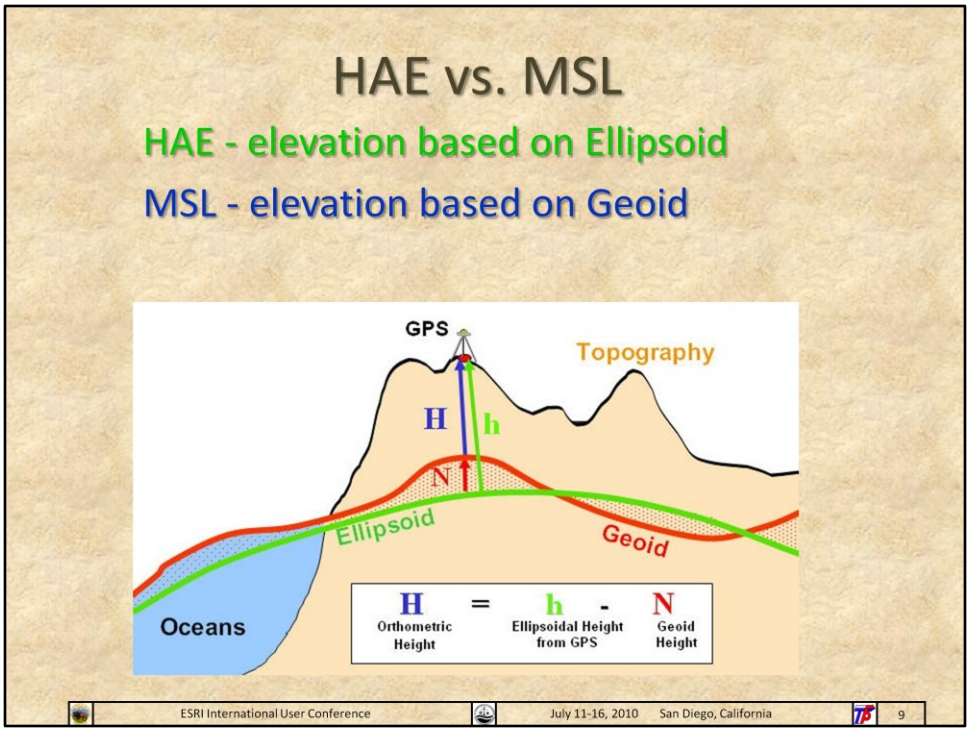
Location of McKinley Mine – North West New Mexico
Semi arid
Low vegetation



Imagery collected in stereo pair – satellite collected 2 shots of the same are from different angles to allow us to extract elevation data.

DEM Extraction Terminology

- **Tie** – Points picked between stereo-pair images (no X,Y, & Z)
- **X Y Points** – Horizontal control points selected from reference ortho-image
- **GCPs** – Ground Control Points; survey grade (full X,Y, & Z)
- **GPS** – Points collected by inspectors. Only used for checking results
- **RMSE** – Root Mean Square Error, measured in pixels
- **HAE** – Height Above Ellipsoid (Z)
- M**SL** – Mean Sea Level (Z)



In this illustration, the green line representing the Ellipsoid is lower than the red line representing the Geoid; as a result, you can sometimes get a negative HAE value.

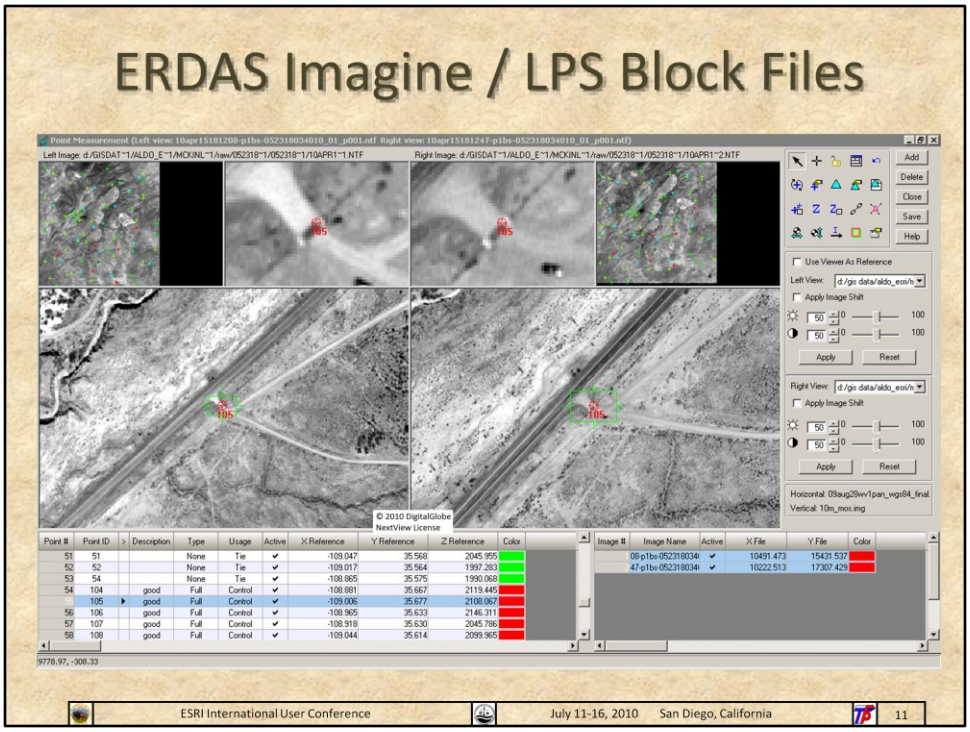
Methodology

Block File	Elevation Type	RMSE (pixels)	Check Point Accuracy GCPs (m)	Check Point Accuracy GPS (m)
Tie	HAE			
XY + Tie	HAE			
GCPs + Tie	MSL			
GCPs + Tie	HAE			
GCPs + XY + Tie	MSL			
GCPs + XY + Tie	HAE			

Different methods

For all methods, a 10m DEM from NED / USGS.

When the GCPs were imported, the entire block file would take the unit in which the points were imported (MSL or HAE)

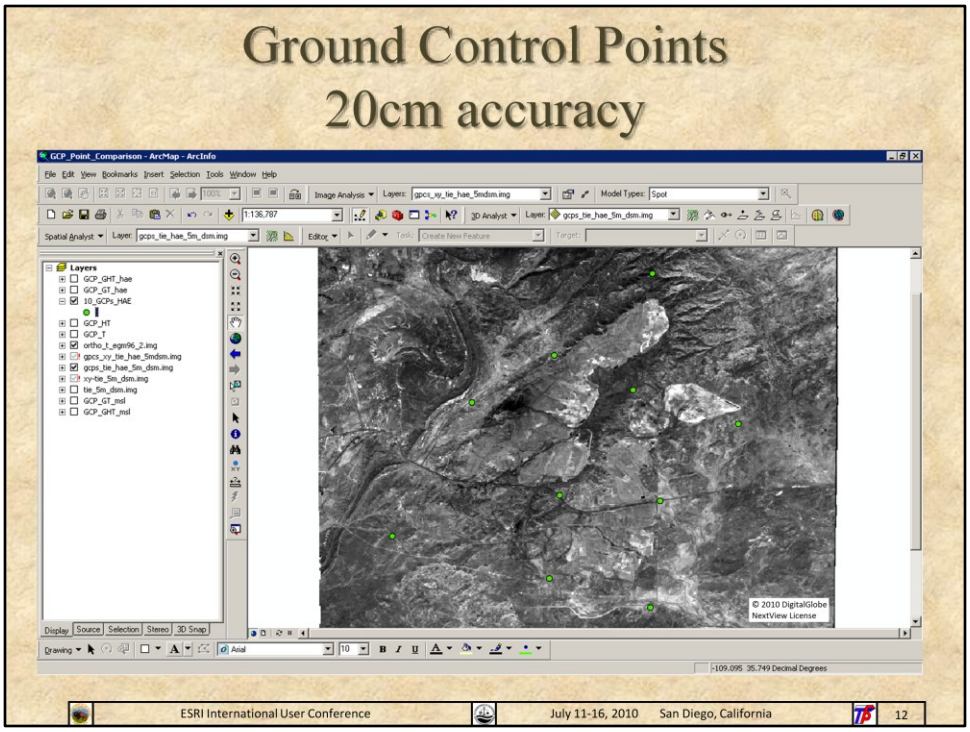


The DEM extraction was done in LPS / ERDAS Imagine 10.1
This is the block file that uses tie points, GCPs, and XY points.

Green Points – Tie points selected from just the stereo pair imagery

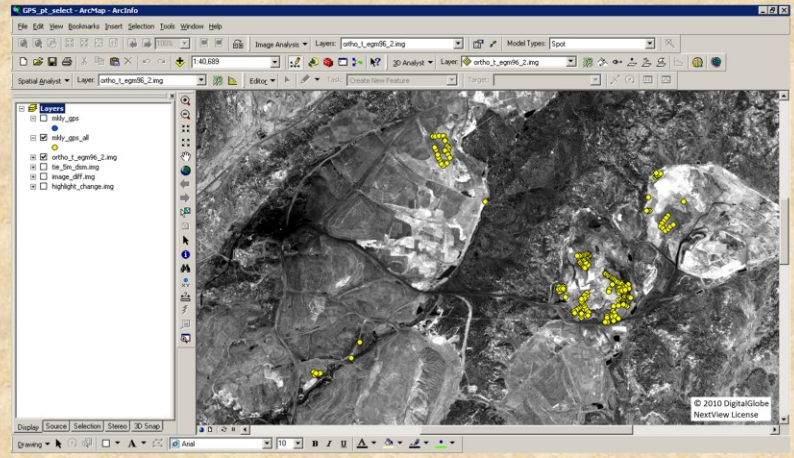
Red Points – Ground Control Points with a full accurate X,Y, & Z reference

Turquoise Points – XY points from a reference orthorectified image

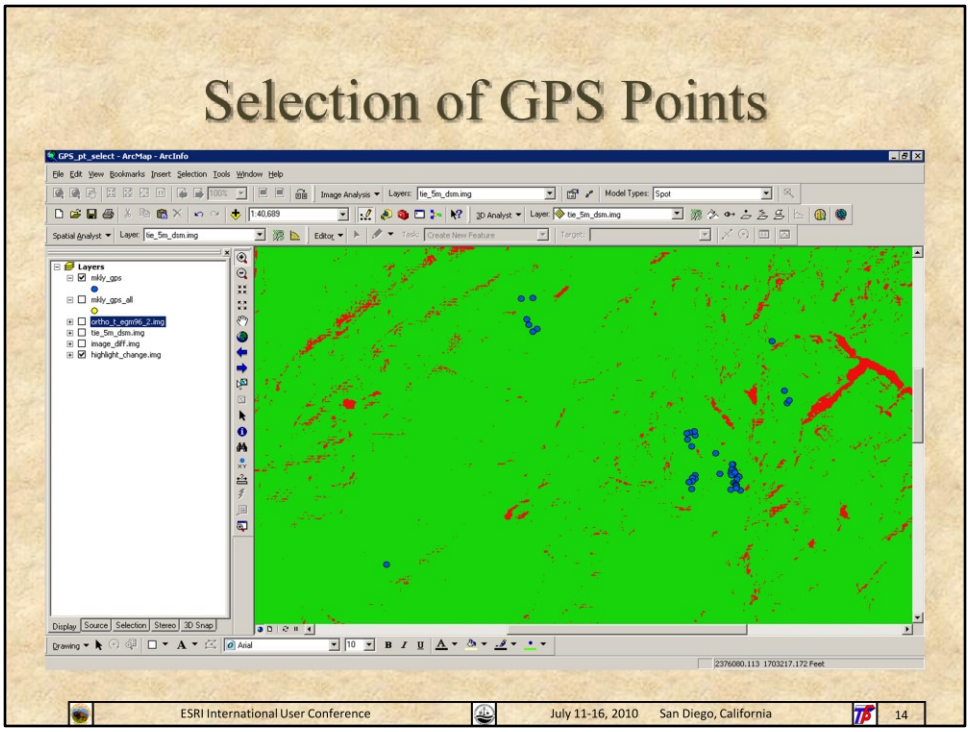


Total of 10 GCPs
Accurate to 20 cm in X,Y, & Z
Purchased from CompassData in 2009
In locations easily identifiable on imagery such as a road intersections

GPS Points



Total of 202 points collected by our field inspector using a hand-help GPS unit
Collected only in the mining area
Although points have X,Y, & Z, we only used them to check the Z

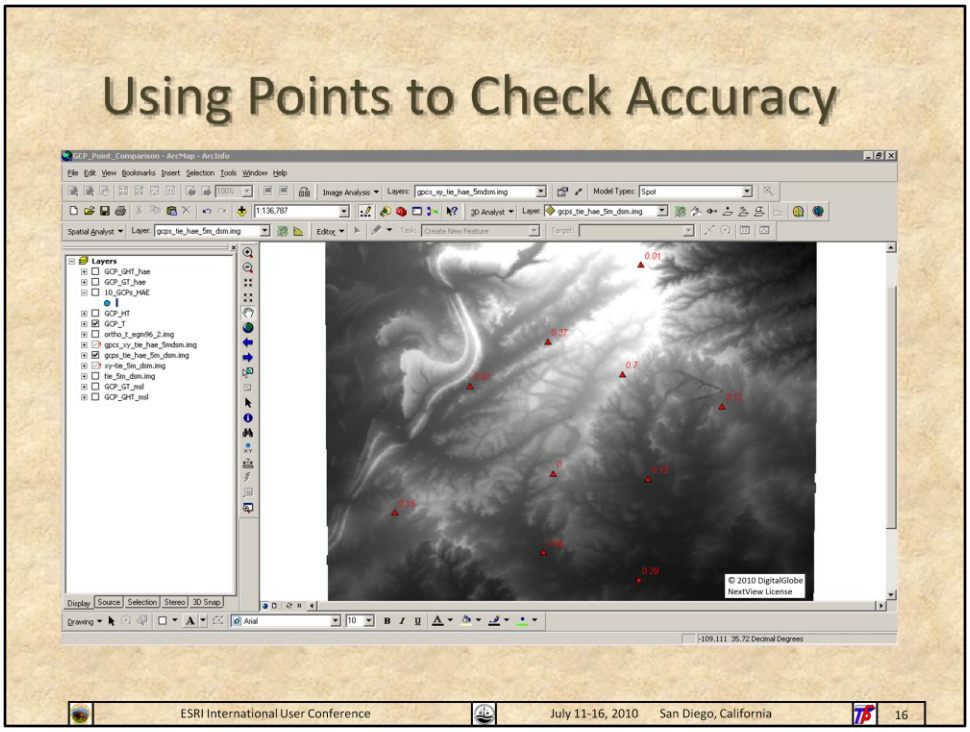


Started with 202 points
Eliminated points with lower precision (inaccurate by more than 1m)
Conducted change detection of an August 2009 and April 2010 DEMs
Green represents areas where there has been no change in elevation
Red represents areas where there has been change. You can clearly see the mining pit in red
We eliminated points in areas where elevation had changed over time (those that were in the read areas)
We ended up using used 43 – Shown blue

RMSEs

Block File	Elevation Type	RMSE (pixels)	Check Point Accuracy GCPs (m)	Check Point Accuracy GPS (m)
Tie	HAE	0.138		
XY + Tie	HAE	0.282		
GCPs + Tie	MSL	0.423		
GCPs + Tie	HAE	0.408		
GCPs + XY + Tie	MSL	0.343		
GCPs + XY + Tie	HAE	0.337		

When adding reference data to a project, you are introducing error, therefore getting a higher RMSE, but what we are really looking at is how the data matches up to our GCP and GPS points.



To check for accuracy, we used Spatial Analyst where we overlaid the GCPs and GPS points over the DEM. Then we used the "Extract to Point" tool. This gave us a new point shapefile with the elevation of the point on the raster. By doing basic math, we were able to calculate the amount of offset of the DEM compared to the GPCs and GPS points.

The red triangles show the amount of off set in meters in the Z direction.

Checking Accuracy

Attributes of GCP_T

FID	Shape *	LAT	LONG	HAE	RASTERVALU	ELEV_DIFF
0	Point ZM	35.737105	-108.921091	2318.573	2318.560059	0.01
1	Point ZM	35.698835	-108.967532	2152.333	2152.698975	0.37
2	Point ZM	35.682513	-108.930488	2202.884	2203.587158	0.7
3	Point ZM	35.666501	-108.880842	2098.32	2098.436279	0.12
4	Point ZM	35.676637	-109.006113	2086.908	2086.974121	0.07
5	Point ZM	35.633022	-108.964737	2125.047	2125.046387	0
6	Point ZM	35.630275	-108.917558	2024.55	2024.423584	0.13
7	Point ZM	35.613768	-109.043566	2078.575	2078.423096	0.15
8	Point ZM	35.593895	-108.969834	2020.134	2018.496094	1.64
9	Point ZM	35.580114	-108.922251	1988.916	1988.623779	0.29

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This is the attribute table for the shapefile shown in the previous slide.
The **HAE** column shows the elevation of the GCPs, the **RASTERVALU** shows the elevation of the DEM where that point overlies, and the **ELEV_DIFF** shows the difference between the two elevations.

Vertical Accuracy Results

Block File	Elevation Type	RMSE (pixels)	Check Point Accuracy GCPs (m)	Check Point Accuracy GPS (m)
Tie	HAE	0.138	0.348 (10 pts)	0.653 (43 pts)
XY + Tie	HAE	0.282	4.568 (10 pts)	4.947 (43 pts)
GCPs + Tie	MSL	0.423	0.64 (3 pts)	0.741 (43 pts)
GCPs + Tie	HAE	0.408	0.71 (3 pts)	0.79 (43 pts)
GCPs + XY + Tie	MSL	0.343	0.837 (3 pts)	0.95 (43 pts)
GCPs + XY + Tie	HAE	0.337	0.850 (3 pts)	0.901 (43 pts)

For the methods that did not used the GCPs for the DEM extraction, we used all 10 points to check for accuracy. For the methods were we did use them, we used 7 for the extraction, and left out 3 to check for accuracy.

The values showing the accuracy, are the averages of the off-set of each point.

Here are all the results (looking at the Z) for our different methods.

From this we learned that:

Our reference ortho data introduced more error

There is not a significant difference in between the HAE and MSL elevations

For this specific set of tests, just using the tie points will give you the best results (when only interested in elevation products)

Horizontal Accuracy

- Using just sensor data will give you good results
  - Accurate within 4meters
- Using more reference data will increase processing time, but will increase accuracy in the X,Y, & Z
  - Accurate within 1-2 meters
- Your results are only as accurate as your reference data.

When only using tie points, horizontal accuracy was within 4m
When using GCPs, and horizontal reference, accuracy improved to 1-2m
** The data that you are processing can only be as accurate as the reference data**

Conclusions

DESIRED PRODUCT	BEST METHOD
DEM	TIE POINTS
GOOD **DEM + ORTHO**	TIE POINTS
GREAT **DEM + ORTHO**	TIE POINTS + GCPs

When looking at the whole picture (X,Y, & Z), your reference data will make a more significant improvement in your results compared to just looking at elevation (Z).

Future Testing

- Full accuracy assessment
- More test areas in different environments
- Compare other software
  - ERDAS Imagine
  - ENVI
  - SOCET SET GXP
  - ArcGIS 10

QUESTIONS